New York State Department of Agriculture and Markets

Specialty Crop Block Grant Program – FY2012

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Final Performance Report

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Project 1
Risk assessment and Management of New Challenges in Phytophthora Blight for New York Vegetables

Project Summary

Background and motivation for project:

Phytophthora blight is a devastating vegetable disease caused by the pathogen *Phytophthora capsici*. In New York, it causes losses in bell pepper, hot pepper, tomato, eggplant, cantaloupe, cucumber, melon, pumpkin, squash, zucchini and snap bean crops. Over the past decade, both incidence and severity of the disease have increased, and vegetable producers continue to search for effective control strategies. A significant new challenge arose in the fall of 2011 as flood waters from hurricane Irene and tropical storm Lee moved *P. capsici* onto farms with no history of Phytophthora blight. This happened in the fall of 2012 with super storm Sandy. The objectives of this project were to: 1) assess the impact of major flooding on the spread of Phytophthora blight; 2) use traditional breeding to improve pepper, zucchini, and summer squash varieties with resistance to the pathogen; and 3) use on-farm trials to obtain feedback on new varieties and extend to growers information on how to prevent contamination of clean fields and how to manage fields contaminated with *P. capsici*.

Project Approach

Activities Performed:

Task/Project activities are listed below, with the most recently completed activities at the top of each category.

Objective 1: Risk assessment of P. capsici spread in NY by flooding

We collected about 200 isolates from newly infected farms from across New York. These isolates were tested for mating type and sensitivity to a commonly used fungicide mefenoxam. We found both mating types present in each field and about half of the isolates collected in Eastern NY (primarily the Capital District) were insensitive to the fungicide. This information has enabled us to let growers know that the pathogen has the ability to overwinter in their fields (because both mating types are present) and we recommend that growers in Eastern New York do not use fungicides with the active ingredient mefenoxam to control Phytophthora blight as this fungicide will be ineffective. Additionally, we now have resistant pepper and partially resistant cucurbit varieties.

Specific activities completed for objective 1:

1. Collect P. capsici isolates from newly affected farms.
    a. The isolates collected as part of this grant represent a wide diversity of the pathogen from across New York. It is critical to have this isolate collection as part of our effort to understand pathogen diversity in New York.
    b. We received isolates from one additional newly affected farm in 2015 (Capital District region).
    c. We received only about 10 isolates for characterization in 2014 (all from the Capital District region). There were no major outbreaks in Western NY.
    d. We collected an additional 100 isolates in October 2013 from two farms in Schoharie County. These farms did not have Phytophthora blight prior to the floods of fall 2011.

e. About 80 isolates were collected from a newly affected farm in Ontario County in August, 2013. We believe this pumpkin field was contaminated by soil brought in on equipment from a nearby farm that had Phytophthora blight.
f. We had the opportunity to collect isolates from two farms in the fall of 2012, and collected 25 isolates from those two farms.

2. Characterization of new isolates for mating type and fungicide resistance.
    a. Based on the activities described below, we now know that isolates in Eastern NY are likely to be resistant to the commonly used fungicide mefenoxam. We recommend that growers in Eastern NY do NOT use this fungicide to control Phytophthora blight.
    b. Isolates from 2015 were characterized for resistance to the commonly used fungicide mefenoxam and again found about 50% of the isolates to be resistant.
    c. Isolates collected in 2012 and 2013 (along with the 10 from the Capital District 2014) have been characterized for resistance to the commonly used fungicide mefenoxam. About 50% of isolates from Schoharie County were found to be insensitive – indicating that the fungicide would not be effective in these fields. Isolates from Ontario County were found to be sensitive to the fungicide. Both mating types were found in all fields tested.

    d. The 25 isolates that were collected in the fall of 2012 have been characterized. We have found both mating types and over half the isolates were resistant to the commonly used fungicide mefenoxam.

3. Screen plant materials for resistance to emerging NY *P. capsici* isolates.
    a. During the spring of 2015 Smart screened about 8,000 squash and 10,000 pepper seedlings breed by Mazourek. About 40 squash seedlings survived and they were taken to Mazourek's greenhouse to be planted into larger pots for fruit production. About 200 pepper seedlings that survived are planted in the field at the blight farm and fruit will be collected. These fruit represent the most resistant cucurbit and pepper breeding efforts to date.
    b. About 120 squash and 200 pepper seedlings that survived the 2014 screening were moved to the field and produced fruit so seed could be collected. This seed will be screened again next season.
    c. Screening began in March 2014 using greenhouse tests on potentially *P. capsici* resistant pepper and squash hybrids produced by Mazourek. This includes 10,000 pepper seedlings and 10,000 squash seedlings.

Objective 2: Use traditional breeding to improve pepper and summer squash/zucchini varieties with resistance to New York strains of pathogen.

Mazourek developed pepper breeding lines with resistance to Phytophthora blight and increased the fruit size of these lines. Hot pepper varieties have some resistance to the disease, and varieties tested this summer have a high level of resistance. Summer squash and zucchini varieties have some resistance based on testing of Mazourek's lines in Smart's greenhouse and field tests. This is the first time we have seen resistance in zucchini and summer squash to Phytophthora blight. We have shared this information with private breeding companies, and growers are looking forward to seeing commercially available resistant varieties in the future.

Specific activities completed for objective 2:

1. Increase fruit size of pepper breeding lines, continue development of resistant hot pepper.

a. Additional screening of F3 families was completed in 2015 and excellent resistance was observed.
b. New hybrids were tested for resistance in 2014, plants with excellent resistance along with good horticultural fruit characteristics were identified. Fruit were collected from these plants, and the entire plants (about 35) were brought into the greenhouse for additional screening of F3 families. We now have jalapeno, serrano and cherry hybrid peppers. Seed from these will be tested for resistance.
c. Mazourek made additional crosses during the winter of 2013 and 2014, and these are currently being tested by Smart. The 2013 screen by Smart was delayed due to extremely heavy rains in 2013.

2. Develop resistant summer squash and zucchini
    a. An additional 8,000 summer squash and zucchini were screened in the greenhouse in 2015. About 40 plants with some resistance were kept and are now fruiting. Seeds will be collected for future screening.
    b. Mazourek produced potentially resistant summer squash and zucchini and Smart tested 10,000 of these plants in the greenhouse (winter 2014). Plants that survived the greenhouse screen were moved to the field in June of 2014. Fruit were collected from the most resistant plants, and additional screening will be done in 2015. Resistant zucchini seed will be shared with extension educators for on-farm trials in 2015.

3. Share resistance and know-how with seed industry.
    a. Mazourek and Smart continue to interact with public and private breeders. Smart again tested breeding lines from private breeders in 2015.
    b. Smart tested potentially resistant pepper lines from both public and private breeders at the blight farm in 2014 (about 12,000 plants). Mazourek interacts with breeders from other universities as well as from private industry.
    c. Both Mazourek and Smart have been interacting with public and private breeders to share ideas. Smart tested many breeding lines at the Phytophthora blight farm in Geneva, NY in 2013 and will again during the growing season of 2014.

Objective 3: Extend Phytophthora blight management strategies to vegetable growers

Bornt and Hadad worked with growers in Eastern and Western NY. They held meetings to discuss Phytophthora blight, had Smart come visit farms, and worked with growers to identify the best control strategies for their farms. Growers with Phytophthora blight for the first time are learning to manage the disease with a combination of cultural practices (rotation, improved drainage, and raised beds), resistant varieties, and effective fungicides. This information has been extended to growers through twilight meetings, winter meetings, webinars, fact sheets, and via newsletters. Numbers of participants are included below.

Specific activities completed for objective 3:

1. Use on-farm trials to obtain feedback on new resistant varieties.
    a. Mazourek received feedback from field trials (4 trials) on the resistance and horticultural traits of peppers. Growers saw resistance, but there was still some fruit rot. Horticultural characteristics improved, and growers were enthusiastic about the breeding program.
    b. Mazourek had several on-farm trials with pepper varieties in 2014 (4 trials).

2. Extend information on how to manage fields contaminated with P. capsici.
    a. Additional meetings in 2015 included several farm visits (3 visits), a twilight meeting in Western NY (40 growers), a webinar for beginning farmers (30 attendees), and winter meetings (two meetings with 30 and 32 growers). Mazourek provided an update on

resistant varieties at the Vegetable Breeding Institute Field Days (about 50 people attended).

b. In 2014 Smart gave three twilight meeting talks on Phytophthora (two in July and one in August with 11, 21 and 27 attendees). She also gave talks on Phytophthora blight at three winter grower meetings (in Eastern NY in late February with 76, 50 and 100 growers) and a webinar to beginning growers (25 participants). Bornt was involved in the Eastern NY meetings as well, and has included information on Phytophthora blight in winter and spring presentations (50 growers in winter meetings and 23 in spring), as well as at twilight meetings during the summer (11 and 27 attendees). Bornt also visited two farms with Phytophthora blight in 2014 and provided management strategies. During the fall, Smart gave a talk to a large organic vegetable grower audience about Phytophthora blight (35 organic growers), and also presented information to Extension educators at a State-wide extension meeting (20 extension educators). Mazourek provided an update on resistant varieties at the Vegetable Breeding Institute Field days in August 2014 (40 participants). Mazourek and Smart discussed the potential of new varieties that are resistant to Phytophthora blight at the Freeville Organic Farm Open House in Tompkins County (30 seed producers and growers). Hadad covered Phytophthora blight at a monthly vegetable meeting in Allegany County (12 growers), and interacted with a grower that lost some peppers to Phytophthora blight during the summer of 2014.

c. In 2013 Smart spoke on Phytophthora blight management at a pumpkin school in Delaware County in late October 2013 (16 growers), and at a squash school in Monroe County in early November 2013 (60 growers). Smart, Bornt and Hadad have helped growers on an individual basis in 2013 in Onondaga, Schoharie, Ulster, Niagara and Erie counties (a total of approximately 25 growers on 15-20 farms).

d. In 2012 Smart, Mazourek and Bornt were part of a team that presented a three-part webinar on Phytophthora blight in the fall of 2012 (approximately 25 attendees). Mazourek presented at the Vegetable Breeding Institute field days showcasing Phytophthora blight resistant pepper lines to seed companies serving NY and distributed seed samples for their breeding programs (30 participants). Mazourek also presented at the Freeville Organic Farm Open House in Tompkins County and shared how to source seed for resistant varieties (27 participants).

Significant contributions and role of project partners:

Christine Smart, PI, was responsible for project oversight and made certain that all aspects of the project were on target. She also had general oversight responsibilities for the Phytophthora blight farm, and ensured that all experiments and demonstration trails were being completed. She completed reports and documents measured outcomes. Smart also characterized Phytophtora blight samples and did all resistance screening assays on breeding materials. Smart was involved with many extension/outreach components of the project.

Michael Mazourek, Co-PI, was responsible for the development of pepper and summer squash varieties with resistance to Phytophthora blight. He gave talks on this work at grower meetings and field days and shared new knowledge and seeds with the seed industry.

Charles Bornt, Collaborator, was responsible for establishing grower trials in Eastern NY, scouting fields, coordinating field samples for diagnosis and isolate collection. He obtained feedback from growers on new breeding lines and is making that information available to the seed industry via Michael Mazourek. Bornt has been and will continue to be involved with many extension/outreach components of the project.

Robert Hadad, Collaborator, was responsible for establishing grower trials in Western NY, scouting fields, coordinating field samples for diagnosis and isolate collection. He obtained feedback from growers on new breeding lines and is making that information available to the seed industry via Michael Mazourek. Hadad has been and will continue to be involved with many extension/outreach components of the project.

Goals and Outcomes Achieved

The project had three objectives/goals (described above). The activities for each objective/goal established are listed in the table below along with a comparison of the actual accomplishments.

Activity for each objective/goal	Personnel Responsible	Timeframe	Actual Accomplishments
Objective 1			
Collect P. capsici isolates	Bornt, Hadad	Summer 2013-2015	We collected over 200 isolates during the course of this project.
Characterization of new isolates for mating type and fungicide resistance	Smart	Winter 2013-2014	Isolate characterization is complete. Both mating types were identified in all infected fields and fungicide resistance was observed in Eastern NY
Screen materials for resistance to emerging NY *P. capsici* isolates	Smart, Mazourek	2014	The first greenhouse screen (10,000 plants each of pepper and squash) was completed during the spring of 2014 and plants were grown in the field over the summer. Using seed from that trial, we did a second screen in 2015 in which plants showed an even higher level of resistance.
Objective 2			
Increase fruit size of pepper breeding lines, continue development of resistant hot pepper	Mazourek	Duration of project	New hybrids are available and were tested for resistance and horticultural characteristics in 2014. Based on feedback we are now looking at fruit rot as well as crown rot symptoms.
Develop resistant summer squash and zucchini	Mazourek	Duration of project	We are really excited about the resistance we have identified in squash, which looked even more promising in 2015 than it had in 2014.

Share resistance and know-how with seed industry	Mazourek, Smart	Summer field days and winter reports	Both Smart and Mazourek are working with public and private breeders
Objective 3			
Use on-farm trials to obtain feedback on new resistant varieties	Smart, Bornt, Hadad	Summer 2014, 2015	These trials started in 2014 (too much rain in 2013) and continued in 2015.
Extend information on how to manage fields contaminated with *P. capsici*	Smart, Bornt, Hadad, Mazourek	Duration of project	Smart, Bornt and Mazourek were part of a three-part webinar on Phytophthora blight; Smart made on-farm visits during the Summer 2013 Smart gave two talks in the fall of 2013. She also gave 8 talks and a webinar in 2014, with additional talks in 2015. Mazourek, Bornt and Hadad gave talks and both Bornt and Hadad worked directly with vegetable growers impacted by the disease.
Update *P. capsici* website	Smart	Duration of project	The website was updated in early 2015

Beneficiaries

Beneficiaries of this project include vegetable growers in the State of New York and beyond. The number of growers who benefitted from this was 250, managing approximately 4,000 acres.

New York ranks 5th in the nation in the value of the fresh market vegetable industry with annual total farm-gate value of about $500 million. In New York, approximately 1/3 of the vegetable acreage and 40% of the value is susceptible to Phytophthora blight.

Specialty Crop Block Grant funds have enabled cutting-edge research to help growers combat this destructive disease. The overall estimated benefit to New York farmers ranges from $2.7 – 5 million.

Lessons Learned

The most exciting lesson learned from this project is that there is some resistance in cucurbits to the Phytophthora blight pathogen. Prior to this project, we had not identified any resistance outside of pepper. While the identification of resistance is exciting, we also recognize the difficulty in developing varieties with both resistance to Phytophthora blight and horticultural traits that growers desire. Because of the devastating nature of this disease, growers are active partners in our research to identify the best suite of control strategies, and this partnership has been very fruitful and satisfying.

Additional Information

See **http://phytophthora.pppmb.cals.cornell.edu/**

Publications from this project include:

Dunn, A.R. and Smart, C.D. (2015) Differential interactions of *Phytophthora capsici* with resistant and susceptible pepper cultivars. *Phytopathology* in press

Dunn, A.R., Lange, H.W., and Smart, C.D. (2014) Evaluation of commercial bell pepper cultivars for tolerance to Phytophthora blight. *Plant Health Progress* 15:19-24.

Wyatt, L.E., Dunn, A.R., Falise, M., Reiners, S., Jahn, M.M., Smart, C.D., and Mazourek, M. (2013) Red harvest yield and fruit characteristics of *Phytophthora capsici*-resistant bell peppers in New York. *HortTechnology* 23:356-363.

Dunn, A.R., Wyatt, L.E., Mazourek, M., Reiners, S., and Smart, C.D. (2013) Performance and tolerance to Phytophthora blight of bell pepper varieties. *HortTechnology* 23:382-390.

Images that may be of interest are included below:

Figure 1. Pumpkin field destroyed by Phytophthora blight.

Figure 2. Smart holding a winter squash infected with Phytophthora blight at a twilight meeting in Eden Valley (Western NY) in August 2015. The meeting was organized by Hadad, and was well attended.

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Project 2
Growing Quality Hops for New York Brewers

Project Summary

The hop industry in New York has been undergoing a rapid expansion. Since the time Prohibition was repealed the industry has been centered in the Pacific Northwest. In fact, hops had essentially not been commercially grown in New York at all from 1950 to 2000. In 2002, only two growers planted hops on a commercial scale.

In November of 2011, 185 growers participated in a conference supported with SCBG funds from a previous project (FY2009). As a result of that project, producers indicated they would be planting over 110 new acres of hops in 2012 and 2013. However, in order for this fledgling industry to succeed, growers need to be able to produce a crop that can compete with the quality of hops from the Pacific Northwest. It is critical that New York growers be able to produce a product that is acceptable to brewers and that has measurable qualities.

This new SCBG project was the next logical step to develop a critical mass of quality hop production in New York in order to support necessary services such as processing and marketing.

Quality is affected by pests, plant vigor, harvest maturity and post-harvest processing and storage. At the onset of this project, there were only a few growers in the State that had the experience and equipment to meet the above criteria.

The goal of this project was to increase in the amount of NY hops being used by brewers. To do so we concentrated on developing and disseminating information and appropriate scale technologies to assist hop growers in growing and processing hops of the quality that brewers require. Brewers have indicated that they will pay a premium for NY hops as long as the quality and quantity exits. Most brewers require dried, pelleted hops that have been tested for brewing quality. Testing the crop is key for determining quality. Brewers make their recipe determinations based on chemical analysis by variety. This project sought to address those needs.

Project Approach

This project provided staff training and addressed the needs of the rapidly expanding hop industry. This project not only sought to further increase the amount of New York hops being grown and sold to brewers, but it also served to address the quality standards brewers require. These goals were advanced through development and dissemination of new educational materials and opportunities for beginning growers, as well as to provide additional technical assistance and advancement to growers who acquired knowledge from a previous SCBG project.

This project was primarily a grower education program utilizing Cooperative Extension methods and resources. Based on his experience working with commercial fruit and vegetable producers, the project leader created and implemented a comprehensive program utilizing research from across the United States. This involved working with faculty, Extension staff and experienced growers who had practical knowledge and hands on experience working with hops. A group of Extension and Land-Grant faculty in a dozen states from Minnesota to Vermont and New York had periodic conference calls where common issues of growing and processing hops were discussed. This became a regular activity and was extremely valuable to everyone in the group, ultimately benefitting growers from multiple States.

The project leader also worked closely with the Northeast Hop Alliance (NeHA) board and growers as advisors. The NeHA website was used for outreach to the vast majority of growers in New York and entire Northeast. A monthly newsletter was created that addressed various aspects of hops production and processing, primarily based on seasonal issues/needs. The newsletter was placed on the NeHA website and is archived there for public access. Each time the newsletter was uploaded, an email blast was sent to established hop growers as well as to individuals who requested information on growing hops commercially. By the end of the project, the distribution list was well over 1,000.

In addition to the newsletter, the project leader provided a series of educational opportunities for growers including educational events/forums and summer field days at hop farms. An annual hops conference was held the first week of December each year in which numerous hops topics were covered (The specifics of all of these events are provided in the "Goals and Outcomes Achieved" section.).

The day before each annual conference, the project leader held a researchers' meeting with faculty, growers, extension staff and most of the conference speakers. This created a valuable opportunity for multiplying the project outreach and served to refine priorities for conference and project activities.

Because of the extensive outreach activities of this project, it did not take long for interested parties all over the Northeast to become aware that there was now a resource person for commercial hop production in New York. The project leader fielded over 2,500 email and telephone requests for information from current and prospective growers.

Goals and Outcomes Achieved

The overall goal of the project was to increase the quantity and quality of hops being grown in NY. Specifically, the goals and outcomes included:

Goal 1

The amount of hops being sold to brewers in NY will increase by 200% between 2012 and 2014. (Goal) A least 30 hop growers will sell their hops to brewers. Ten growers will increase their planted acreage in the project.(Targets) 50 Growers will be surveyed in 2012 to establish bench mark data on sales to brewers.(Benchmark) Growers and brewers will be surveyed at the end of 2014 to determine sales to brewers. (Performance Measure)

Some of the benchmark data was derived from surveys given to growers at the annual hops conference. The great majority of commercial growers in New York attend this event each year. A survey instrument was developed in 2012 and used at that conference for a benchmark and following conferences to track the industry. Although the attendance at these events was high, many growers did not complete the survey each year. By looking at membership data on the NeHA website we obtained a very close approximation to the total number of acres and number of commercial growers in the State. Based on this, we know that only about one third of the growers gave us data via the surveys at the conferences. However, even with considering that information, the goals of this project were exceeded. By using NeHA member data we know that by 2014 there were over 1,000 growers and acreage had increased to 225 acres (from 16 acres in 2011).

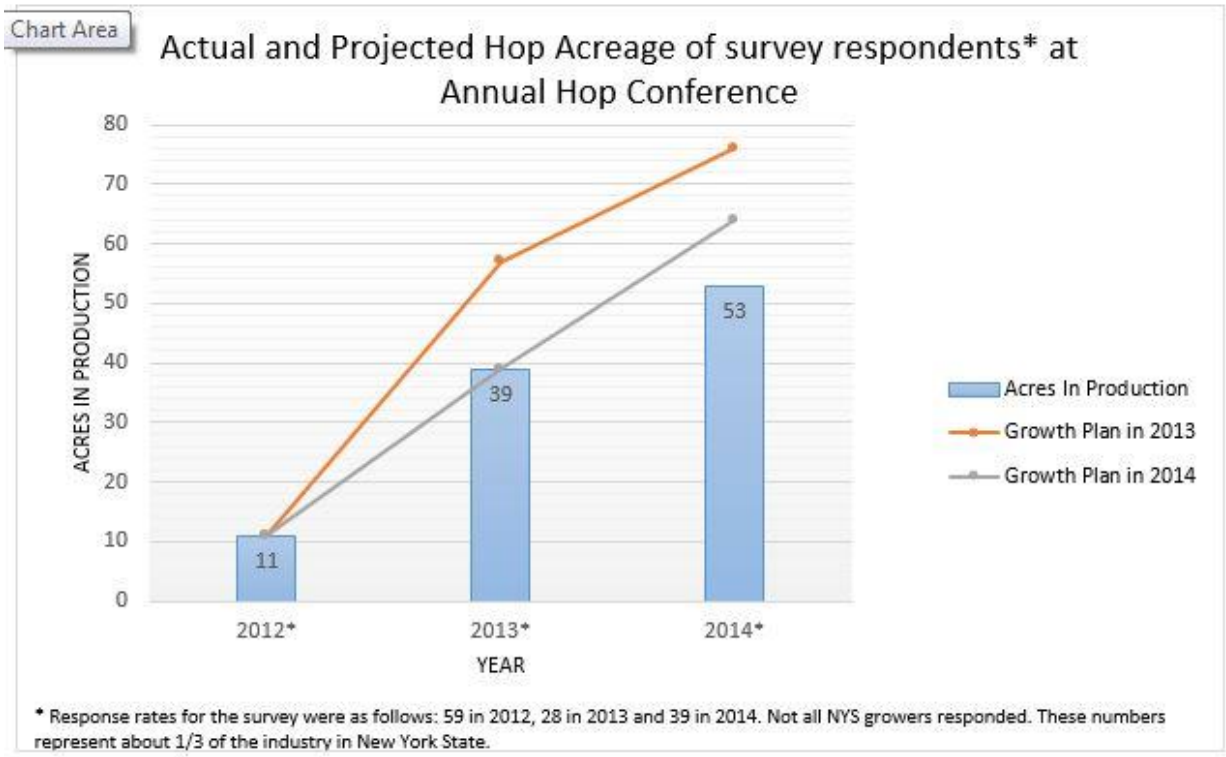


Figure 1: Acreage in hops increased from 2012 to 2014.

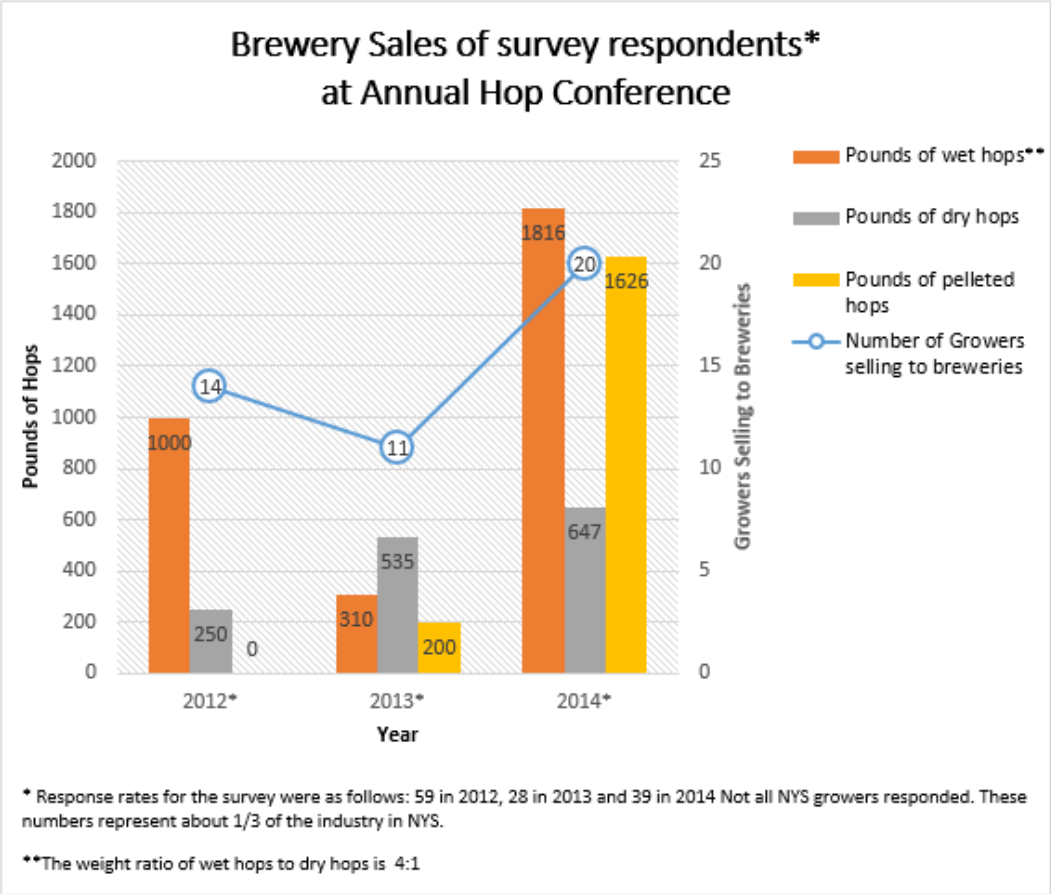


Figure 2: The quantity of hops sold directly to breweries has increased between 2012 and 2014.

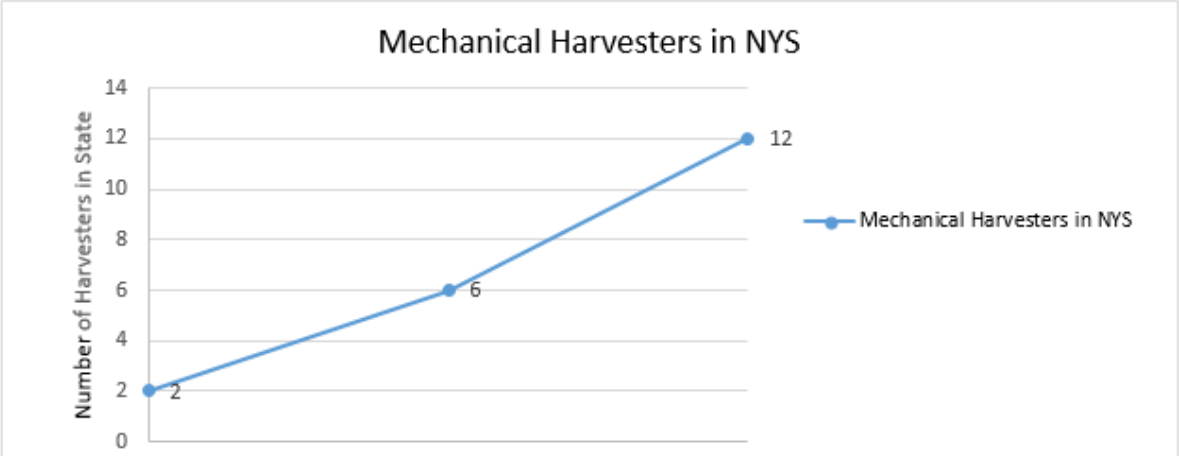


Figure 3: The number of mechanical harvesters in NYS increased six-fold from 2012 to 2014.

Goal 2

To establish the quality of the hop crop produced in New York. The quality of the New York hop crop will be measured. (Goal) Chemical analysis is common practice in major hop production areas. Currently, only a few growers are having their crop tested. They will be surveyed in 2012 to determine the extent of testing and some baseline data of quality. (Benchmark) 30 growers will have

their crop tested for two years. These growers will provide brewers with the results to support sales. The availability of hops processing in NY will increase. 4 growers will invest in hop processing equipment and will process for themselves and other growers. (Targets) Data will be collected by variety and grower, from the crop analysis during 2013 and 2014 for industry comparison. (Performance Measure)

During this project a group of growers were contacted as cooperators. The project leader approached an analytical lab to have all of the samples done, rather than each farmer sending their samples to different labs. This helped to ensure analysis uniformity. It also reduced project costs as the lab was able to reduce the cost of services. As a result, we were able to have more samples analyzed. Samples from each grower were sent out for analysis. This included the alpha and beta acids, total oils and hops storage index. These are the primary quality characteristics that brewers require in making decisions on what to purchase and how much of each particular hop to include in a batch of beer.

A key element of this project was the collection of data on hops quality analysis. The information on the importance of having an analysis done was shared with the group of 30 key project cooperators, as well as with the general grower population in New York. They were also instructed on how to submit their sample and on techniques for drying, moisture level testing and packaging. Fifty samples were analyzed for 2014. That information, along with the results from 2013, have helped to evaluate the progress on crop quality for the industry. Individual growers will also be able to use this information with their brewer customers to verify the quality of their crop.

In 2014 we offered a hop evaluation program where growers submitted samples of hops in both dried whole leaf and pellets. Fifty samples were submitted and 18 brewers participated in evaluating the samples for various qualities including visual and smell. Brewers provided written evaluations using a form we developed to provide guidance and ensure uniformity. In addition, brewers were able to purchase hops from the growers who submitted samples.

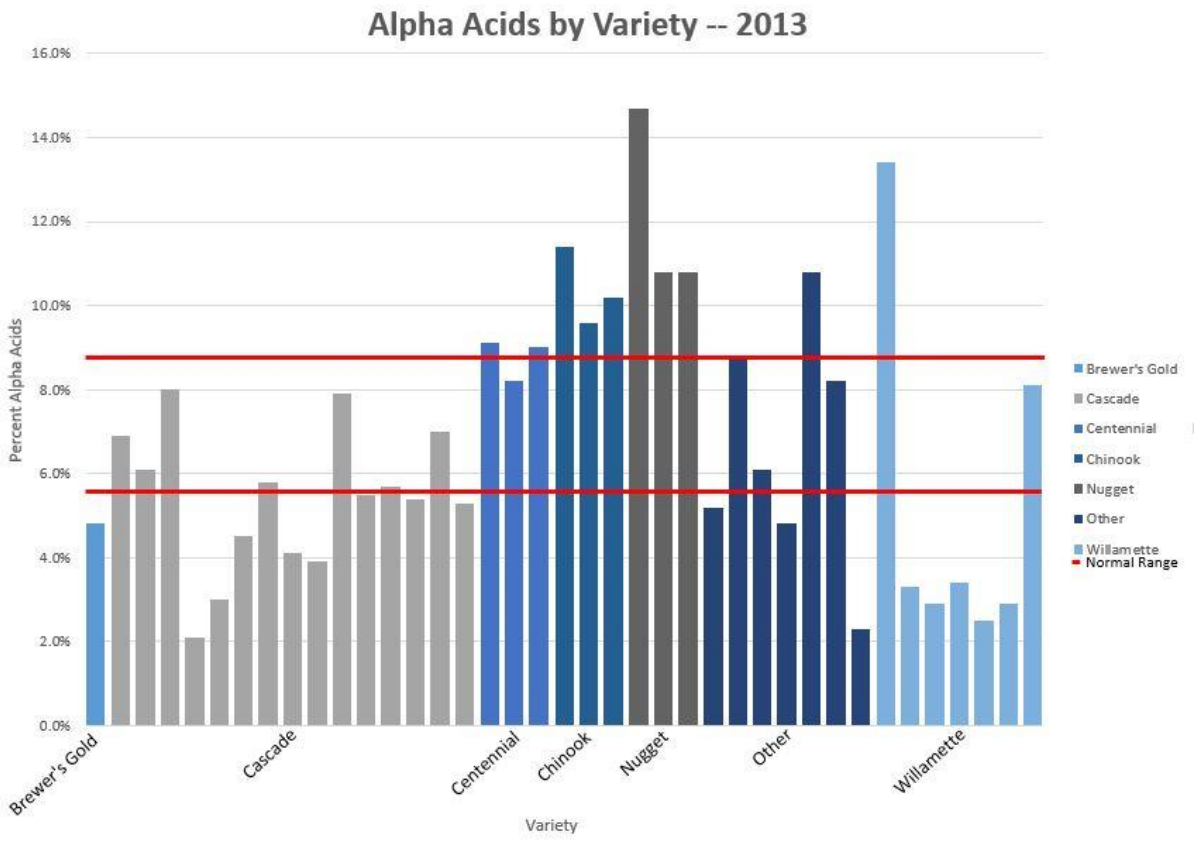
Selection of the varieties for testing was determined by the importance of the variety for brewing and the frequency with which it is found in New York. The following graphs show the results for the hop crop analysis tests including: alpha acids and beta acids (which contribute to bitterness), total oils (which contribute aromas important in most craft beers), and HSI – hops storage index – (which gives an indication of the condition of the hops for storage).

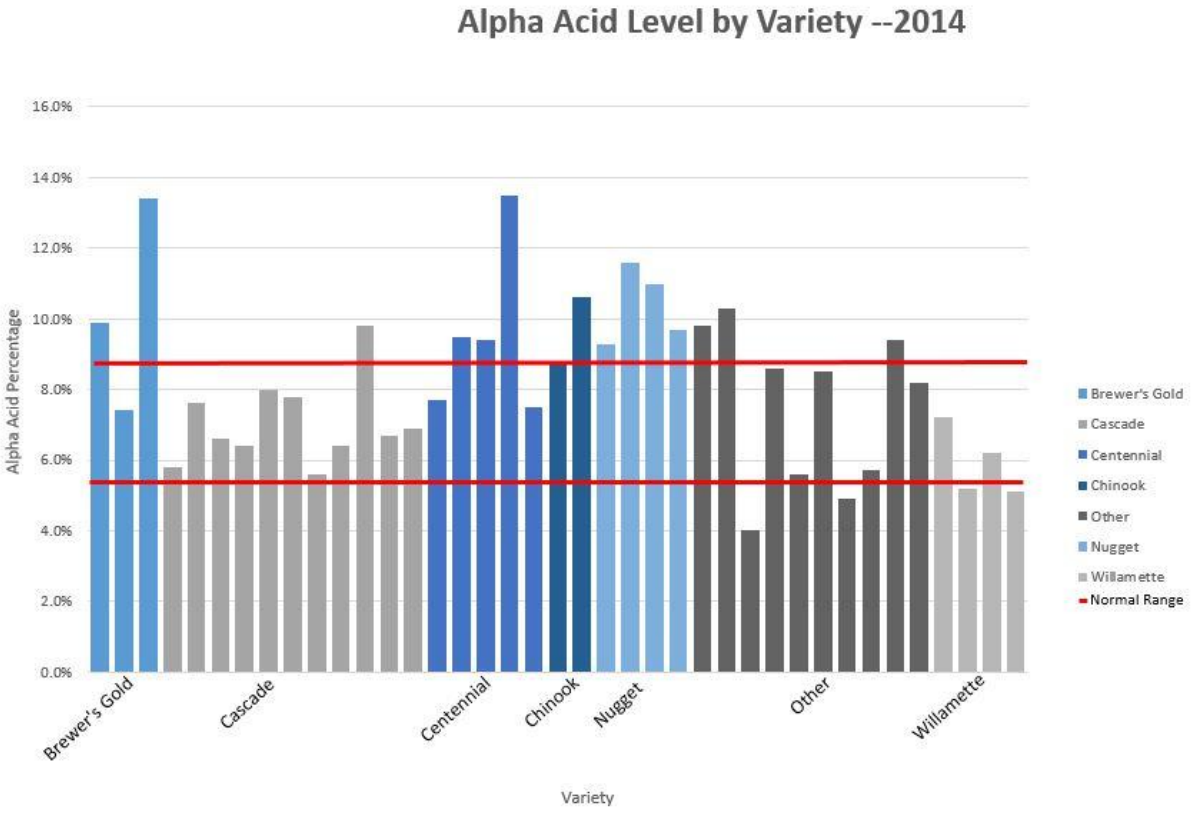
In the following charts, we see in Cascade -- an important aroma variety -- that the alpha levels are within industry standards from the Pacific Northwest (5.6-8.8%). The total oils are also very favorable, in line with industry standards for the Pacific Northwest (between 0.6% and 1.9%).

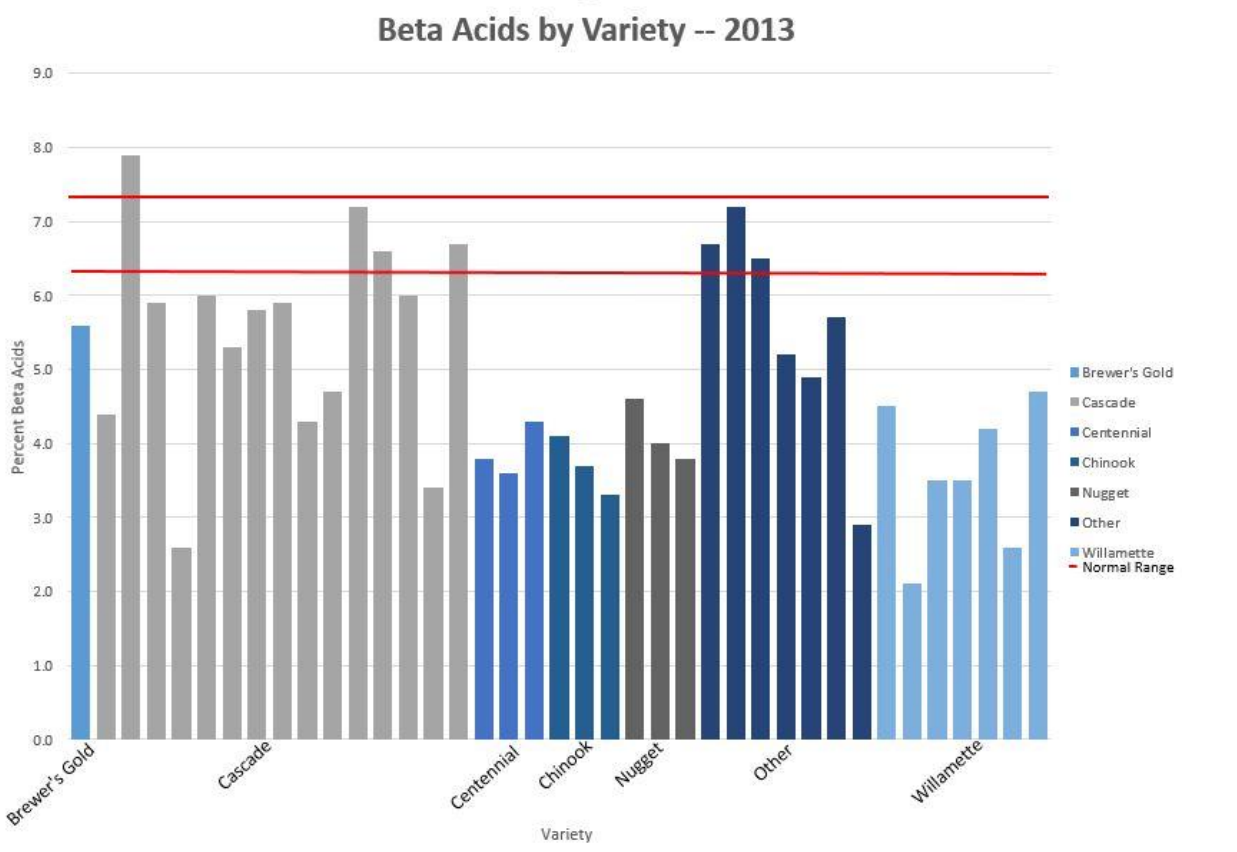
For Centennial, which is more a dual purpose variety, the alpha level should be between 8.8% and 10.9%. Most of the samples fell within this range. The oils in New York hops in some cases were 1-2%, which is even higher than those from the Pacific Northwest.

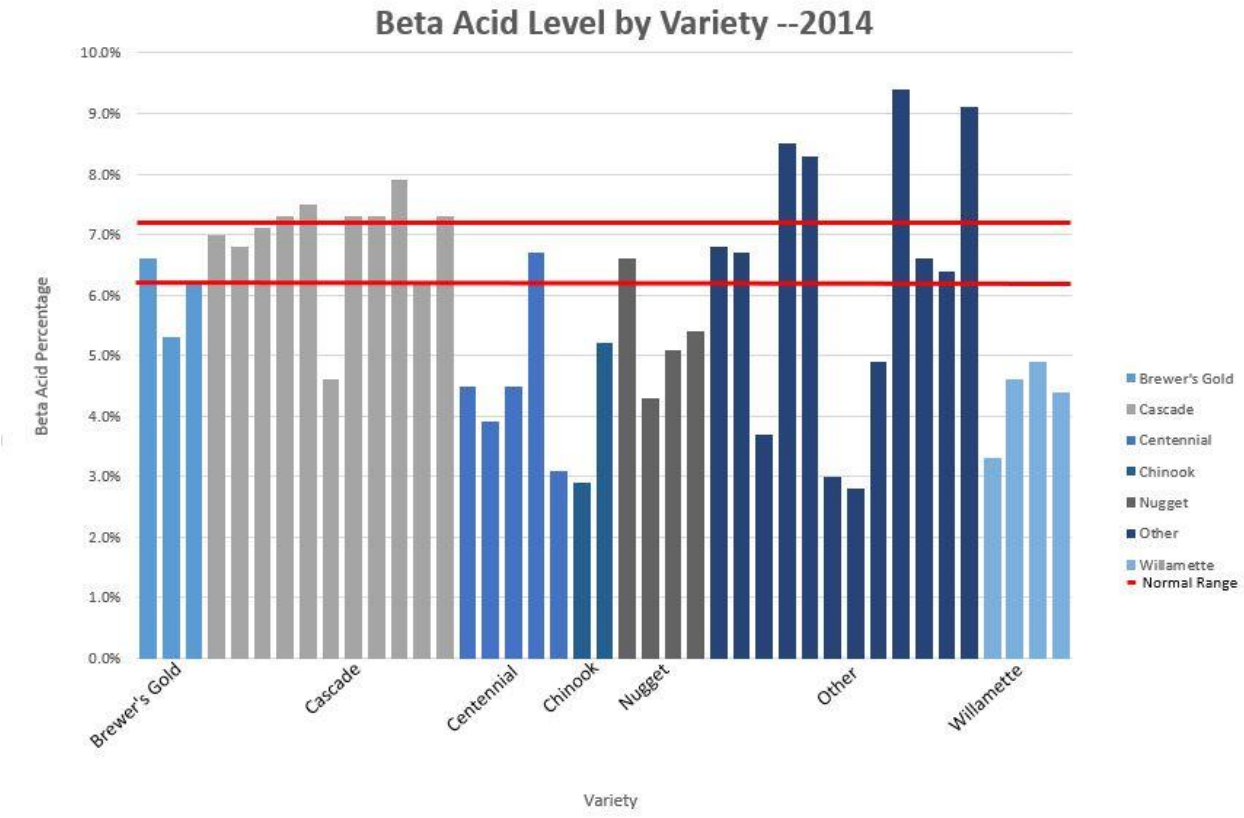
The New York Nugget grown samples were slightly lower in alpha acids and total oils, but still in a good range.

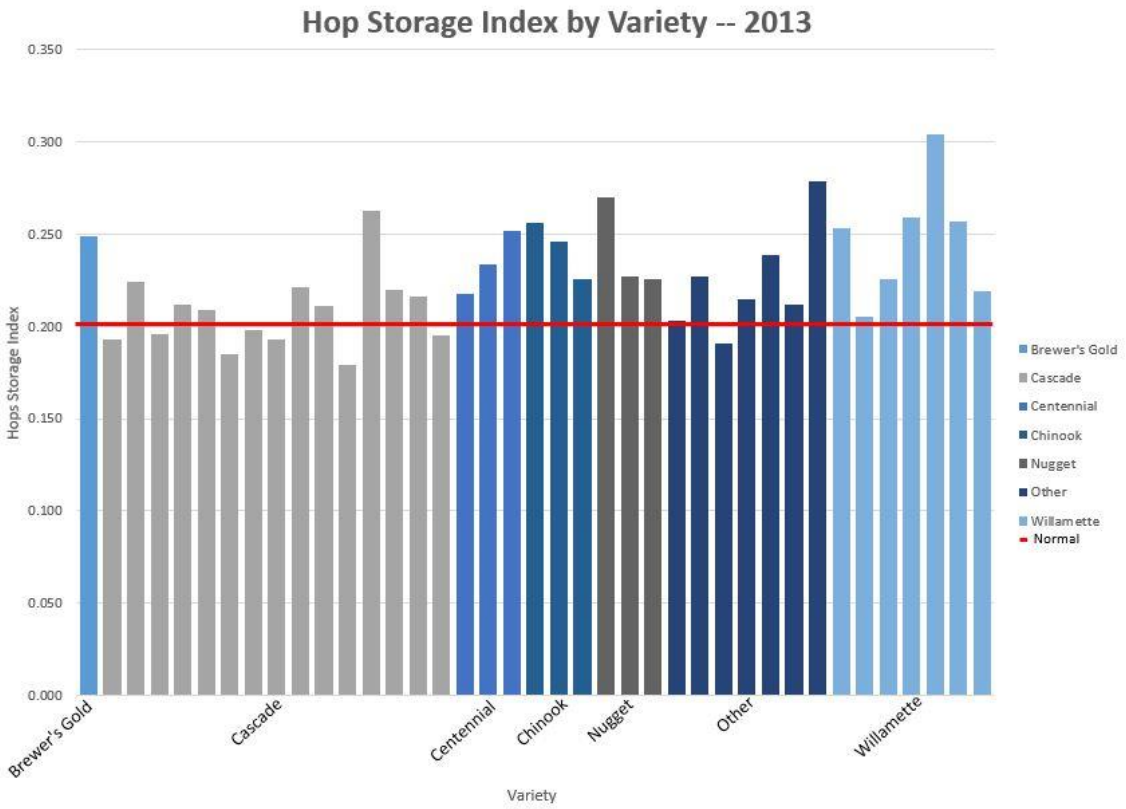
Most of the samples were collected from hop yards that are relatively young. As the plants and the growers' abilities mature, we expect that most varieties will perform well. These data are indicating that hops grown in New York will be able to provide the quality that brewers require. We still have a way to go to improve yields.

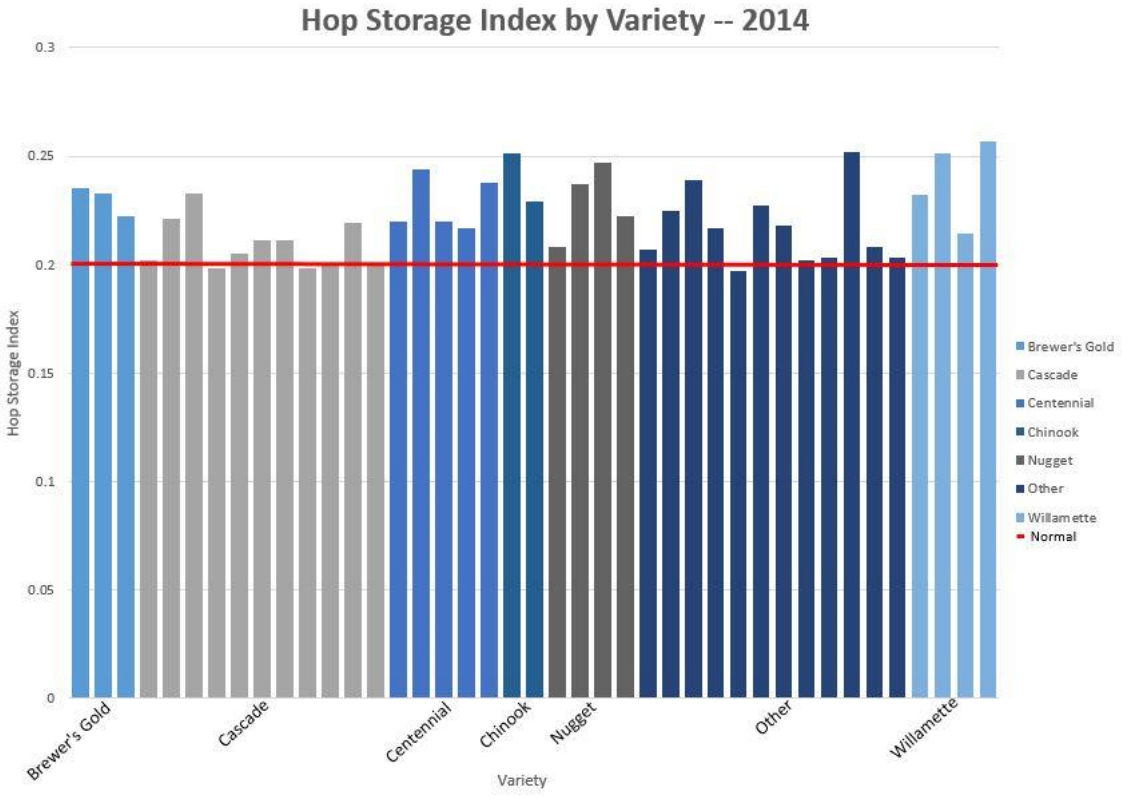

Alpha Acids by Variety -- 2013
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
Percent Alpha Acids
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Variety
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Normal Range

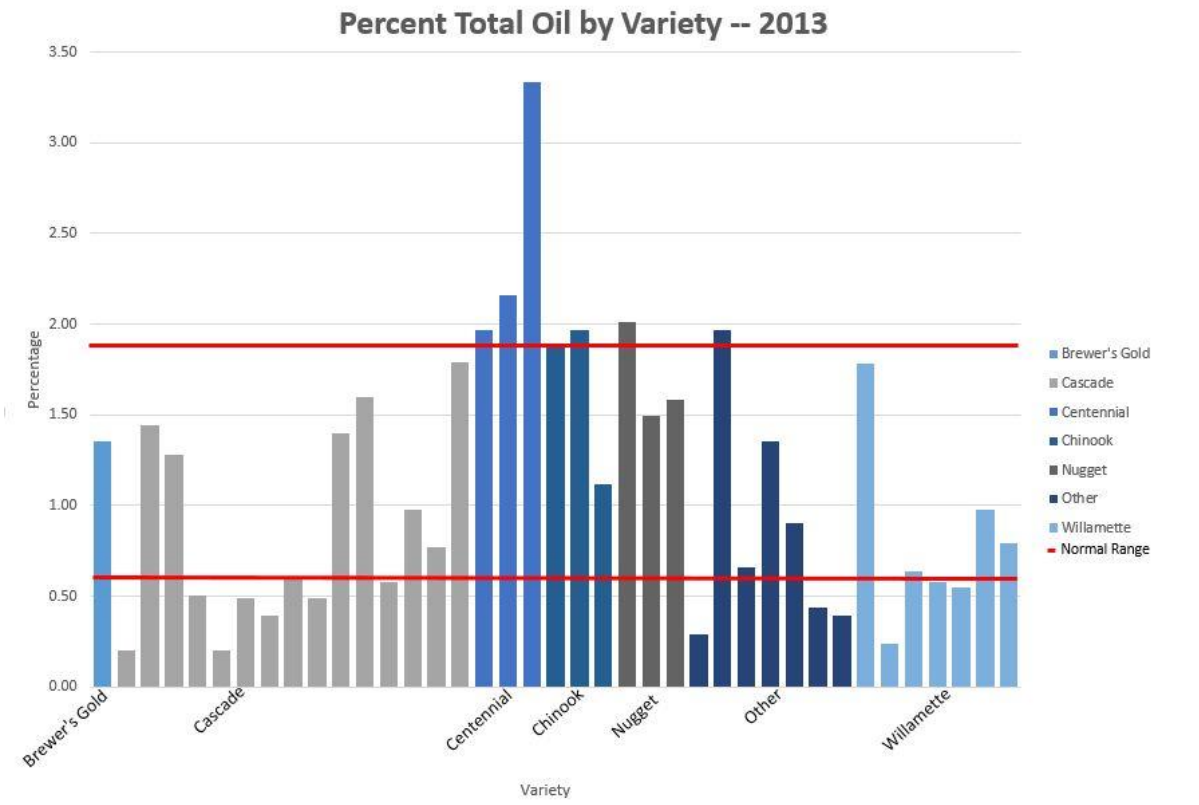

Alpha Acid Level by Variety --2014
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
Alpha Acid Percentage
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Variety
Brewer's Gold
Cascade
Centennial
Chinook
Other
Nugget
Willamette
Normal Range

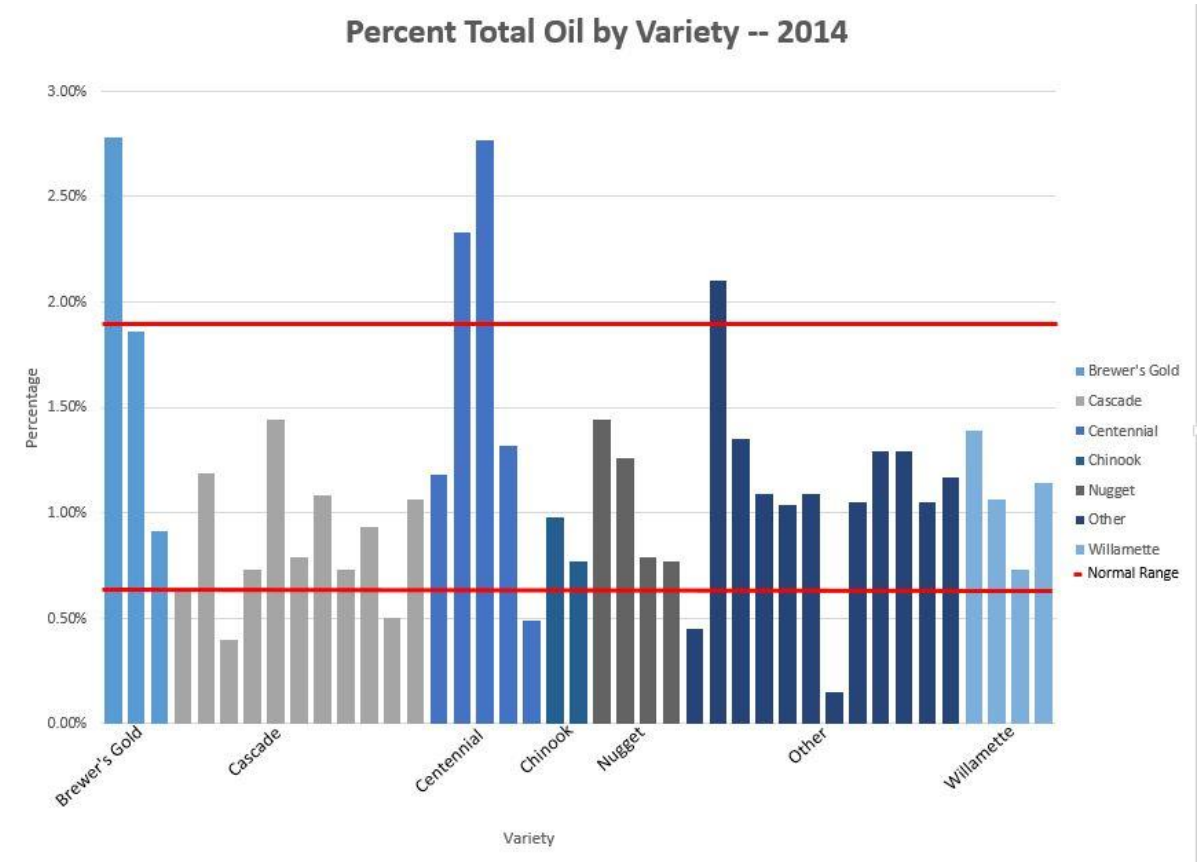

Beta Acids by Variety -- 2013
Percent Beta Acids
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Normal Range
Variety


Beta Acid Level by Variety --2014
Beta Acid Percentage
10.0%
9.0%
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Normal Range
Variety


Hop Storage Index by Variety -- 2013
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Hops Storage Index
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Variety
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Normal


Hop Storage Index by Variety -- 2014
0.3
0.25
0.2
0.15
0.1
0.05
0
Hop Storage Index
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Variety
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Normal


Percent Total Oil by Variety -- 2013
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Percentage
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Variety
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Normal Range


Percent Total Oil by Variety -- 2014
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
Percentage
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Variety
Brewer's Gold
Cascade
Centennial
Chinook
Nugget
Other
Willamette
Normal Range

The second part of the hops quality goal was to encourage and provide information to growers who could offer harvesting, drying, pelletizing, and packaging services for themselves and other growers. As such, the project leader traveled to Poland to investigate the machinery used in Europe. Poland hops farms are much smaller scale, about 25 acres, than farms in the Pacific Northwest and are more similar to NY operations. Five growers in New York asked the project leader to source equipment for them and have it shipped back to their farms. The growers paid all expenses so there were not grant funds expended. This included 4 Wolf pickers, 6 drying oasts, 1 mechanical harvester with a self- unloading trailer and several pieces of cultivating equipment. This allowed these growers to benefit from the use of the equipment, but also other growers who were close enough to them to utilize it. Four of these growers have also set up facilities to process hops for other growers. An added benefit was that many other growers in New York were able to see this equipment in use first hand and find out what it would cost to obtain it. This created a learning experience beyond seeing the machinery on line.

By the end of the project there were at least eight companies in New York who had purchased equipment and were offering services to pellet and package hops. We now have enough processing capacity for growers to expand and meet the standards that brewers require.

Goal 3

Hop growers will learn appropriate management and production techniques for commercial hops production. (Goal) The great majority of hop growers in N Y are new, and lack detailed knowledge and experience in hop production and pest management. (Benchmark) 40 growers will attend regional field meetings and conferences and receive electronic newsletters that teach them appropriate management strategies. This will include site selection, disease resistant varieties, cultural practices, and trellis layout and design. (Target). Attendance at 6 events over 2 years will be taken as well as the list of growers receiving 6 newsletters/yr. (Performance Measure).

This project had a major outreach component, especially since the project manager was working with a new, developing industry in New York. Information and resources were provided to the target population with a multi-faceted approach. During the project there were 18 newsletters sent to an audience that began with about 300. By the end of the project, the newsletter was being emailed to over 1,200 people representing a variety of production stages or interest levels. The newsletter regularly contained specific information related to the goals in the project. Each newsletter was placed on northeasthopalliance.org and was archived so growers may refer back to information previously presented. Over 1,200 people received an email with a link to this website each month.

In addition to the newsletter, there were other resources on the NeHA and University of Vermont websites. This exposed many new prospective growers as well as current growers to the information related to project activities/resources.

Growers were, and still are very thirsty for information to advance their skills in growing hops. The project leader presented information at 16 events around the State during the time frame of the project. Approximately 800 people attended at least one of these events. In addition, the project leader held a yearly Cornell Hops Conference, the first week in December of 2012, 2013 and 2014. Over 350 people attended each year.

Empire Farm Days, held in August, has also been a successful method to reach farmers considering hops production. Many thousands of farmers attend this event each summer. A steady stream of participants came by the Cornell Hops Program booth. The project leader or a staff assistant were there for the three days to answer questions.

In 2013 the project leader also was a contributing author for the new *Cornell Integrated Guide to Producing Hops*. Growers of most other crops in New York have long had access to

guidelines that contain detailed information on site selection, fertility practices and pest management. This new guide for hops is being used by growers in New York and other States. At the time this report more than 100 copies have been distributed.

During the final stage of this project, 32 growers were surveyed to track their progress. Of the 25 growers who responded, 72% reported having gained knowledge about site and variety selection and 88% reported having gained knowledge about fertility practices. As they expanded the acreage of their hop yards, 72% of growers were able to apply the information they learned about site and variety selection to their expansion. Furthermore, 68% of the growers reported having improved their fertility practices as a result of the information they learned through the Cornell Hops Program. The growers who had not applied the knowledge to their yards unanimously expressed the need to use better fertility practices, but cited lack of resources – especially time, money, and equipment -- to do so. Twenty growers felt they gained knowledge about harvesting hops. Of those growers, 16 implemented improved harvesting techniques on their farms. Harvesting hops by hand is very tedious and is not practical on a large scale. Group learning opportunities, including lectures and the annual conference helped smaller growers link up with larger growers who had the harvesting and processing equipment required for large scale hops production.

	Feb. 2013 - Oct. 2013		Nov. 2013 - Jan. 2014		Feb. 2014-April 2014		May 2014 - July 2014		Aug. 2014-Dec. 2014	
	Location	**Reach**	**Location**	**Reach**	**Location**	**Reach**	**Location**	**Reach**	**Location**	**Reach**
Newsletter	Online	6*400	Online	3*450	online	3*450	Online	3*400	Online	3*1300
Meetings	CLEREL Lab	122	State Beer and Wine Summit		Vermont Hop Conference	175	Seneca County	100	NEDLOH Hopfest	60
	Onondaga County	46	Annual Hop Conference	360	Syracuse Brew Fest		Soil and Water Meeting	46	Dutchess County Extension	65
	Soil and Water District Staff Mtg.	1200	Catskill Ag Conference	30	Utica Brew Fest	55	Mann Library	65	Madison County Hop Fest	55
	Farm Bureau Mtg.		The Carey Center	55	Tap NY	125	CLEREL Lab	95	National Craft Beer Conference	32
	NYS Brewers Association		Farm Brewer Conference	45	NY Brewers Association	100	Adirondack Meeting	58	Erie County Extension	65
	NY Master Brewer Association		Fruit and Veg Expo	65	Farm Brewers Meeting	35	NYS Agriculture Bankers Association	65	Annual Hop Conference	380
	Geneva Experiment Station Brew School		USDA Webinar	100			Geneva Field Day	81		
	Seneca County		Annual Hop Conference	285						
	5 Field Meetings (Across NYS)									
	4 Other Meetings									
E-mail and Phone Consults		850+		740		610		750		675
Other Projects	Crop Quality Analysis		Cornell Hops Guidelines		Purchasing trip to Poland		Hop Quality Analysis		Hop Quality Analysis	
	Vacuum Sealing Regulations		Crop Quality Analysis		Cornell Hop Guidelines		Hop Scouting		Hop Scouting	
					Hop Scout Grant Awarded					

Table 1: Outreach activities and reach from February 2013 to October 2014

Beneficiaries

There are several groups of beneficiaries from this project. The first of which are the new hop growers in New York. These growers have had access to a number of educational opportunities that they would not have otherwise had. At the beginning of the project, there were 65 growers who had planted hops in New York with a total of approximately 60 acres. This project offered information and assistance for producers to grow their acreage. By the end of 2013, these numbers increased to 95 growers with over 110 acres. By the end of the project, there were 135 growers with 225 acres. In addition, the number of members of the New York chapter of the Northeast Hop Alliance (a grower organization) increased to over 250 members. These include people who are growing hops currently as well as those who are interested in exploring hops production.

This brings up another group of beneficiaries – individuals who decided not to plant hops. The project leader held numerous educational events and sent out newsletters to over 1,000 people each month. He also had direct contact with many hundreds of potential hop growers by email, phone, and personal visits over the course of the project. The great majority of these contacts resulted in the client not planting hops immediately. Some decided to hold off on planting because they learned that they were not ready to do so, often because they had not adequately prepared the site. Others decided the crop was not a good fit for them because of labor requirements, lack of funds, or a number of other reasons. The project leader considers these outcomes just as important as decisions to enter the hop business. It is much better for someone to find out that the crop is not for them before they make a large investment in money and time.

The brewing industry, and ultimately consumers, also benefit from the development of locally available hops. Growers are now able to provide hops that have been analyzed for quality and are in the product form that most brewers want -- namely dried, pelleted and packaged in materials that preserve the quality. The amount of product that will reach the market will continue to increase as both the acreage increases and the crop reaches peak maturity.

Lessoned Learned

One of the issues that occurred during the course of this project was the overwhelming interest of people wanting to get into the business of growing hops commercially. The project leader did not have any difficulty in convincing growers to attend outreach opportunities as interest in market opportunities were already strong. Attendance at meetings was excellent, in fact some people had to go on a waiting list for the conferences. Even though growers have been willing to share information with their colleagues, we still have a difficult time getting them to fill out surveys regarding their acreage and sales figures to brewers. This is especially important with a new crop industry. With future projects, significant effort should be made to convince growers of the importance of providing this information.

Another lesson we learned regarding the hop evaluation program was that it needs to be held earlier in the fall, instead of at the annual conference (December). The reason behind having the evaluation program at the annual conference was to assemble as many brewers directly with growers as possible. Interestingly, most brewers want to see whole leaf hops, even though they primarily buy pelleted hops. Unfortunately for the purposes of this exchange, the majority of growers already had most off their crop pelleted and much of what was left had already been sold.

Additional Information

Figure 1: Hops baler capable of making bales up to 100 pounds

Figure 2: Northern Eagle hop processing pelletizing machine is capable of processing up to 400 pounds per hour

Figure 3: Brewers examining hops at the hop evaluation

Figure 4: Hop drying equipment made in Germany

Figure 5: Hops waiting to be pelleted

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Project 3

Cooperation with NY Grapevine Nurseries to Establish Disease-Tested Increase Blocks

Project Summary

The life of a vineyard is typically 25 years or more. The production and profitability of a vineyard is a direct function of the quality of the planting stock. Planting material free of pathogens is essential for high quality grape production and the sustainable management of vineyards. Viruses are common in grape planting stocks. Pathogens such as viruses are vegetative propagated along with the buds and rootstocks. If present in the propagation material, these pathogens will be perpetuated in progeny vines that will be planted in NY vineyards.

This project facilitated the development of disease-tested planting stocks to improve the health status and productivity of grapevines in New York as well as the establishment of a grape certification program to monitor the health and status of propagated vines.

Project Approach

Three meetings were held jointly between representatives of NYS Department of Agriculture and Markets (NYSDAM), Cornell, and New York nursery growers. Additional meetings were held with each of the individual nursery growers. Details on the establishment of a certification program were outlined. Presentations on the project were made at four industry grower meetings (Finger Lakes Grape Growers' Conferences in 2013, participants = 80, and 2014, participants = 200; 2013 Western NY Winter Conference, participants = 150; 2014 Fruit and Vegetable Expo, participants = 100). We visited vineyards and worked with growers. Growers did not identify mother vines, but opted to pursue disease testing of their selected vines. Growers did not opt to tag and winter sample tagged vines. As an alternative, they provided samples with their own labeling for disease testing. Virus testing was performed throughout the project period, including 3,070 vine samples using serological assays or array testing.

Plant samples from nursery sites were submitted by the four participating nursery growers or collected by the investigators. The sources were Grafted Grapevine Nursery, LLC, Hermann J. Wiemer Nursery, Double A Vineyards, and Dr. Konstantin Frank Vineyards.

Goals and Outcomes Achieved

Goal 1. To work with nursery growers and extension personnel to identify grapevine rootstocks and varieties of greatest importance to the eastern U.S. grape industry with regard to the establishment of increase blocks. Accomplishments include four meetings with four nursery growers and two extension personnel. The grapevine rootstocks and varieties of greatest importance were identified as those in production in the respective nursery operations.

Goal 2. To perform in-season observation, sampling and disease testing of nursery mother blocks to identify and label vines that will serve as cane sources for propagation. Accomplishments include onsite visits at each of the nursery growing sites and to commercial vineyards, testing for viruses as requested by growers and providing test results to facilitate grower management of vines.

Goal 3 To perform disease testing of dormant canes from mother vines to be used to plant increase blocks or from vines of existing increase blocks if established. Accomplishments A total of 3070 vine samples were virus tested (dormant and in season), establishing the disease status of these vines.

The baseline for this project was that no *active* certification scheme for grapevines in NYS was in place. One of the outcomes of this project was to establish methods and approaches that can be used by NYS; these were established in the joint grower and NYSDAM meetings described above. Performance measures were met through presentations on diseases, testing programs, and the importance of certification that were discussed at annual Finger Lakes Grape Growers' Conferences and other grower and industry meetings. The certification program will be launched by NYS Department of Agriculture & Markets – Division of Plant Industry in 2016. The PI has been working with multiple New York grape nurseries to identify the presence of economic significant viruses in their grapevines. These grapevines are used for vegetative propagation of additional vines and rootstocks.

Beneficiaries

The primary beneficiaries are the four nursery growers and farms that represent the grapevine nursery industry in the northeastern US. The secondary beneficiaries are the 1,600 grape growers and farms in New York State that purchase planting materials.

The four participating nursery growers were able to obtain extensive evaluations of the health status of their planting stocks. This allowed them to identify healthy planting stocks to continue propagating and virus-infected planting stocks to discontinue working with.

The economic impact of viruses can be substantial for the grapevine nurseries and the wine and grape industries, if planting material and stocks are virus infected. This is estimated to range from $9,695 (for a 30% yield reduction and no quality penalty) to $16,014 per acre (for a 50% yield reduction and a 10% penalty for poor quality) Finger Lakes of New York. Thus, the identification of clean stocks and the production of clean planting material can save the industry $9,695 to $16,014 per acre for new plantings.

Lessons Learned

Productive relationships can be established with growers to provide them with information on viruses and assist them in managing viruses in their vines.

Changes in grower practices directed toward re-establishing a certification program will take time.

Additional Information

Below are papers relevant to grapevine viruses in NY that were published during the funding period. These were not a direct outcome of this project, but part of a broader effort to address disease problems of grapevine in NY.

Vargas-Asencio, J. A., Al Rwahnih, M., Rowhani, A., Thompson, J. R., Fuchs, M. & **Perry, K. L**. (2015). Limited genetic variability among American isolates of Grapevine virus E from Vitis sp. *Plant Dis* **(**Accepted for publication) http://dx.doi.org/10.1094/PDIS-05-15-0556-RE.

Sudarshana, M. R., **Perry, K. L.** and Fuchs, M. F. (2015). Grapevine red blotch-associated virus, an emerging threat to the grapevine industry. *Phytopathology* 105, 1026–1032.

Krenz, B., Thompson, J. R., McLane, H., Fuchs, M., and **Perry, K. L.** 2014. Grapevine red blotch-associated virus is widespread in the United States. *Phytopathology* 102:1232-1240.

Thompson, J., Fuchs, M., McLane, H., Toprak-Celebi, F., Fisher, K., Potter, J., and **Perry, K. L.** 2014. Profiling viral infections in grapevine using a randomly primed reverse transcription-polymerase chain reaction/macroarray multiplex platform. *Phytopathology* 104:211–219.

Celebi-Toprak, F., Thompson, J., **Perry, K. L.,** and Fuchs, M., 2013. Arabis mosaic virus in grapevines in New York State. *Plant Disease* 97:849.

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Project 4
Exploiting Natural Stress-Induced Resistance to Disease

Project Summary

Powdery mildews affect several New York specialty crops, including grapevine, strawberry, apple, and major vegetable crops such as cucumber, pumpkin, and squash. Their highly evolved relationship with plants makes them remarkably effective pathogens. However, it's also an "Achilles Heel" that can be exploited and used against them.

All powdery mildews are biotrophs, meaning they can only exist on living plant tissues. They are sensitive, if not susceptible, to all of the natural factors that can stress a plant. Current disease forecasting systems are well attuned to direct effects of the environment on a pathogen. These are factors such as temperature, rainfall, and humidity that currently drive many of our forecasting systems.

We have recently discovered that naturally occurring acute cold events (2 to 10° C) will suppress grapevine powdery mildew by stimulating the natural resistance of the host. Preliminary work indicates a myriad of suppressive effects associated with minimally stressful environmental factors.

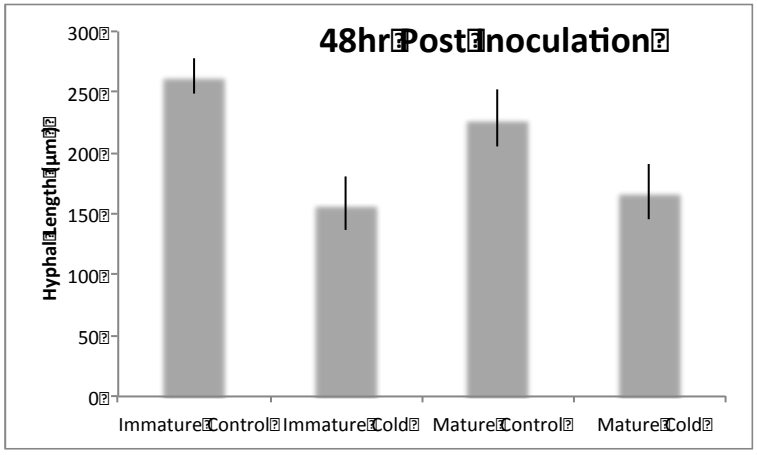
Grapevine powdery mildew was a perfect model system in which to study how we can use naturally occurring stressful events (e.g., cold nights or hot days) to better predict when fungicides should be used, and when they can be safely withheld. Our objective was to quantify the effects of natural environmental stress upon development of powdery mildew to improve forecasting systems. As a result of this project, it became apparent after several pilot studies on strawberry and cucurbit that these hosts do not respond to cold shock. However, we were able to demonstrate that cold and heat operate as general stress factors that alter susceptibility to powdery mildew of grapevine.

Project Approach

Powdery Mildew (*Erysiphe necator*), a destructive pathogen of grapevines, is distributed worldwide. The pathogen is native to North America, and all European wine grapes (*Vitis vinifera*) are highly susceptible. Presently, management relies on fungicide applications based on models developed under controlled and constant temperatures. Recent work in our lab (Moyer et al. 2010) demonstrated that overnight low temperature events (2-8° C) can suppress extant colonies, and promote transient resistance to new infections. We call this effect Acute Cold Disease Suppression (ACDS). To date, ACDS has only been demonstrated in younger, more susceptible leaves. Our objective in this study was to compare ACDS of grape powdery mildew in younger leaves to older matured leaves where it would act in conjunction with ontogenic resistance.

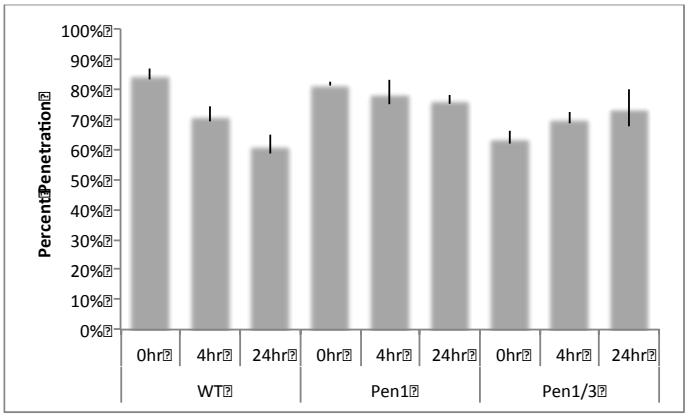
We expanded our activity to encompass cold-induced responses in cucumber and strawberry. We also expanded the study to encompass cold-induced responses in mature grapevine leaves. These leaves already exhibit a high-degree of ontogenic resistance to powdery mildew. Thus, this was the first time we were able to demonstrate the operation of cold-induced disease resistance in mature, ontogenically-resistant leaves, as opposed to young ontogenically susceptible leaves. As mature leaves account for an increasing proportion of the plant canopy as the growing season progresses, this represents a significant finding for the project. Stress-induced resistance operates in all cohorts of the grapevine canopy.

Cold-Induced Disease Suppression in Mature Leaves



Eight susceptible (leaf 3) and 8 resistant (leaf 5) leaves of *Vitis vinifera cv.* Chardonnay were collected from our research vineyard and greenhouses and plated on double-petri dishes. 4 susceptible and 4 resistant leaves were then incubated at 4°C for 4 hr., while the remaining leaves were kept at 23°C in the growth chamber. The leaves were then inoculated with a single isolate spore suspension and incubated in our growth chamber at 23°C for 48 hr. or 72 hr. The leaves were cut into disks and cleared, stained, and rated for (i) hyphal growth, and (ii) colony development.

Secondary hyphae production on both the immature (I) and mature (M) samples decreased in cold treated leaves at both 48hr and 72hr intervals. There was also a reduction in secondary hyphae length in both the cold treated immature and mature leaves at both 48 hr. and 72 hr. intervals, indicating an ACDS response.



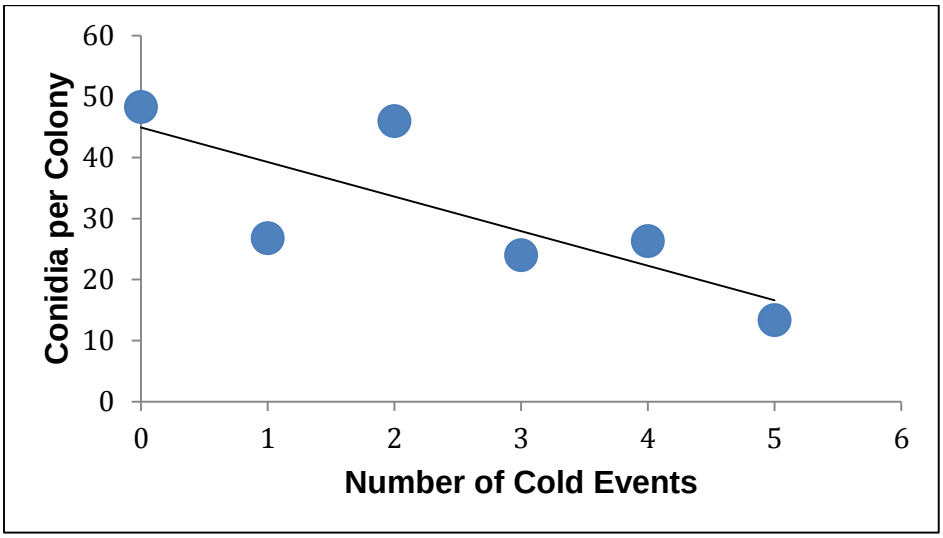
Penetration success of powdery mildew inoculum on leaves of Arabidopsis strains. Penetration decreased as cold shock duration increased in WT strain, but did not decrease in either Pen1 or Pen1/3 (0 and 24 hr.: WT p=0.001, Pen1 p=0.019, Pen1/3 p= 0.185).

Cold-Activated Defense Genes Pen1 & Pen3

We used *Arabidopsis thaliana* as a model organism for parallel studies of powdery mildew infection events. Detached Arabidopsis leaves of a wild-type strain (Columbia 0) and two mutants (Pen 1 and Pen 1/3) were exposed to 4 C for 4 hr. either 4 or 24 hours prior to inoculation with cabbage powdery mildew. Leaves were rated for evidence of colony expansion.

Increased resistance to pathogen penetration is the proposed mechanism by which *V. vinifera* leaves defend against powdery mildew infection. Pen 1 and Pen1/3 are mutants lacking identified penetration resistance genes (Collins et al. 2003). These tests were a way of investigating whether the Pen genes are activated by cold and thereby involved in the mechanism behind acute cold disease suppression.

Preliminary results indicate a decrease in the percentage penetration of "Columbia 0" (WT) cold treated samples. Pen 1 had a significant decrease in penetration percentage at 24 hr. but not at 4 hr. Pen 1/3 did not have a significant decrease in percent penetration in both 4 and 24 hr. treatments.



Effects of repeated cold stress events

When detached Chardonnay grapevine leaves were subjected to sequential acute cold events under lab conditions, there was a progressive decline in health of the colony as measured by production of spores on the colony surface. Under field conditions, this is precisely what happens to extant colonies, and temperatures fall to 10° C or less almost every night for the first four to six weeks after bud break. Increase in severity of the disease can be minimal during this time.

Biochemical Compounds in Cold Stress

In plants, salicylic acid (SA) is a common systematic acquired resistance signaling compound released in response to stress events such as drought, heat, and cold. We used cation-column High-Performance Liquid Chromatography (HPLC) to assay levels of SA in the tissue of immature grapevine leaves that had undergone acute cold exposure (4 hr. at 4 °C). Cold shock resistance has been shown to peak at 24hr, so was used as the HPLC time interval (Gadoury et al. 2013).

Stress-induced disease resistance in strawberry and cucumber

Our studies showed that the magnitude of cold stress-induced disease suppression in strawberry is of lesser magnitude than was observed in grape. Many cultivated strawberries were selected from alpine wild alpine plants, and may thus possess a higher tolerance of cold. Cucurbit detached leaves did not exhibit a cold-induced disease suppression. When compared to attached leaves, it appeared that the act of detaching the leaves itself induced systemic acquired resistance to some degree, and this could mask a temperature-stress induced suppression of infection. However, follow-up experiments using intact plants to remove this as a confounding factor also indicated no substantial effect of cold pretreatment on disease suppression.

Goals and Outcomes Achieved

(i) Strawberries and cucurbits do not respond to cold temperatures in the same manner as was observed in grapevine, and stress-induced disease suppression was neither statistically significant nor commercially relevant.

(ii) SA levels may be unrelated to the observed reaction of biotrophs to exposure of the host plant to acute cold. HPLC studies of SA did not reveal quantifiable levels of SA in

either positive control group.

(iii) We developed a seedling grapevine population from the F1 progeny of a controlled cross of selected parents in grapevine, one of which was devoid of the cold-shock response. This population can serve as the genetic base for an investigation of the biochemistry and genetics of cold-induced disease suppression.

(iv) Our results indicate that Pen 1 and Pen1/3 mutants do not consistently exhibit ACDS, suggesting that they may be genes involved in the cold suppression response.

(v) Powdery mildew epidemics in vineyards are suppressed until night temperatures remain above 10°C.

(vi) In addition to susceptible, immature leaves, Acute Cold Disease Suppression affects matured, ontogenically resistant *V. vinifera* leaves;

(vii) An improved forecast and advisory system for grapevine powdery mildew has been developed and modified based upon the project results.

Comparison of Originally Proposed Goals and Outcomes to Those Achieved:

(i) Our original project proposed parallel research on three commodities. It became apparent after several pilot studies on strawberry and cucurbit that these hosts do not respond to cold shock as does grapevine. Consequently, the research and outreach effort was redirected to maximize impact on a relevant crop system (grapes), rather than continue to experiment on systems with little potential for application.

(ii) In significant aspects with respect to grapevine, we exceeded the originally proposed objectives. We were able to demonstrate that cold and heat operate as general stress factors that alter susceptibility to powdery mildew of grapevine. We demonstrated that the response functions in both young susceptible and older ontogenicially-resistant tissues. Thus, stress-related induced resistance is additive with ontogenic resistance. We furthermore gained insight into the genetic control of cold-induced resistance.

(iii) The ultimate goal of our original project was to improve advisory systems used for management of powdery mildews. With respect to grapevine, this has been accomplished, and the results of this project are now components of advisory systems used worldwide, through our outreach efforts to the local and regional grape industry, and our leadership of the International Powdery and Downy Mildew Workshop.

Beneficiaries

The immediate beneficiaries of the project are the grape growers of NY and the eastern region of North America. Growers of several specialty crops are affected by powdery mildews (*e.g.,* strawberries, apple, cucurbit, bedding plants and ornamentals, turfgrasses, grapes, and many others). However, immediately useful components of our work are primarily applicable to grape growers. There are 1,631 family vineyards and 400 owner-operated wineries in New York (NY Wine and Grape Foundation). On a national scale, there are 23,000 grape producers and 7,200 owner-operated wineries (National Grape and Wine Initiative).

In addition to direct producers, our research benefits other stakeholders, including County Cooperative Extension educators and advisory personnel, private crop consultants, and faculty and staff of the New York State Integrated Pest Management Program.

Organic producers in particular benefit, as ultimately would consumers.

Benefits accrue because producers are less reliant upon chemical fungicides, and the sustainability of management programs has been consequently enhanced**.** A very conservative estimate involving only the present costs of fungicides applied once per year to acreage to suppress mildew (assuming material plus application costs of $50 per acre) would yield a potential benefit of eliminating *only that one spray* in grapes that would equal $1,750,000. Note that many crops would require several fungicide sprays in some years to suppress powdery mildew (*e.g.,* up to seven in grapes, or $12,250,000), and potential benefits would also include the avoidance of crop loss due to catastrophic failures of management programs due to fungicide resistance. In years of region-wide mildew severity, up to 10% yield loss has been reported by NY grape growers, or approximately $5.8 million of farm gate value of NY wine grapes.

Lessons Learned

The significant suppression of epidemic development due to cold overnight temperatures that was observed in the grapevine powdery mildew pathosystem does not apparently have a counterpart in powdery mildews of all crops. Neither cucurbit nor strawberry exhibited a significant suppression of disease when subjected to overnight cold. This was not entirely unexpected in strawberry, which is descended from wild alpine species that could be adapted to cold. However, it was surprising in cucurbit, which is essentially the model plant for systemic acquired resistance (SAR). Although SAR is induced in most cucurbits by a variety of compounds related to environmental stress, acute cold did not result in significant suppression of powdery mildew in repeated assays.

Nonetheless, the response in grapevine was shown to be stable, predictable, and broadly applicable to all sampled grape varieties, and allowed the substantial improvement of an advisory system that is widely used for decision-making in fungicide applications.

Additional Information

Outreach activity: Results of the project were reported at the following stakeholder meetings (attendance in parentheses):

- Annual meeting of the Lake Erie Regional Grape Program and the New York Wine and Grape Foundation at Westfield, NY on Feb 26 2013 (50 attendees).
- Meetings with grower representatives of the E.J. Gallo Wine Company, 4 February 2013 (10 attendees)
- Annual meeting of the American Phytopathological Society in Austin TX, Small Fruit Disease Working Group, 12 August 2013 (1,500 attendees)
- Annual meeting of the Lake Erie Regional Grape Program and the New York Wine and Grape Foundation at Westfield, NY, Feb. 2014 (50 attendees).
- Geneva Summer Scholars poster presentation, Hobart and Williams Smith Colleges, Geneva, NY, July 31 2014 (100 attendees)
- NOFA-NY (Natural and Organic Farming Association of New York), Saratoga NY, 23 January 2015 (250 attendees)
- North American Strawberry Growers Association, Ventura, California, 1-6 February 2015 (1,000 attendees)
- Annual meeting of the American Phytopathological Society in Pasadena, CA, Small Fruit Disease Working Group, August 2015 (1,500 attendees)

Research publications: The results of the project were presented and discussed in the following publications:

- Moyer, M.M., Londo, J. Gadoury, D.M., and Cadle-Davidson, L. 2015. Cold stress-induced disease resistance (SIDR): indirect effects of low temperatures on host-pathogen interactions and disease progress in the grapevine powdery mildew pathosystem. European Journal of Plant Pathology DOI 10.1007/s10658-015-0745-1.
- Moyer, M.M., Gadoury, D.M., Wilcox, W.F., and Seem, R.C., 2015. Weather during critical epidemiological periods and subsequent severity of powdery mildew on grape berries. Plant Disease 99:0000-0000 (in press).

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Project 5
Engaging Tree Fruit Growers to Implement a Stewardship Program

Project Summary

Farms are integral to the identity and economy of Long Island. Suffolk County ranks first in New York in total annual sales of non-dairy farm products ($240 million in sales in 2012). At the same time, Long Island is surrounded by water and it sits above a sole source aquifer providing the principle source of drinking water to its residents. As a result, concern regarding non-point source contaminants impact Suffolk County residents, landowners and the agricultural industry alike.

According to the 2011 NYS Department of Environmental Conservation's LI Pesticide Use Management Plan reported "shallow private wells in agricultural areas are found to be most vulnerable to pesticide contamination, with more than 50% of the samples taken from these wells containing detectable pesticide residues."

Prior to the development of this project, there had not been a standard protocol for Integrated Pest Management specific to Long Island's tree fruit crop. In addition, there were no weather stations on Long Island connected to Cornell University's Network for Environment and Weather (NEWA) program to provide accurate forecasting pest models for this region's microclimates. A primary goal of the project was to enable orchards to improve their pest management practices by monitoring weather conditions, implement a scouting program to correctly identify insects and disease present in orchards, consider and develop economic thresholds and choose appropriate control methods, which included: >50% use of reduced risk, minimum risk, bio-pesticides, pheromone mating disruptions, pest traps, organic materials, "low input" conventional products and the judicious use of conventional pesticide materials where necessary.

Growers often need technical and financial assistance to adopt Best Management Practices (BMP's) to protect ground and surface waters. A universal concern expressed by the agricultural industry when approached with changing their management practices to reduce and/or eliminate environmental impact is the costs related to changing practices and the fear (whether real or perceived) of crop loss that will impact their bottom line and economic sustainability. This is a significant concern in Suffolk County where costs for production and land values are so high growers are dependent on producing high value crops to stay profitable. Finding a balance of remaining economically viable while environmentally sustainable is a major challenge. These concerns were the motivating force in developing this project.

Project Approach

Cornell Cooperative Extension, Suffolk County's Agricultural Stewardship Program primary performance goal for this project was to engage three tree fruit farms on approximately 165 acres in a comprehensive IPM demonstration project (with the expectation that >50% of pesticides used by the 3 participating orchards would be "low-input". The secondary goal was that the growers would use the RainWise weather stations and Cornell University's Network for Environment and Weather Applications (NEWA) Program for forecasting pest and disease, thereby reducing and/or better managing insects and disease.

The result of this project and the work accomplished has far exceeded our initial goals and objectives. Eleven apple and five peach orchards have participated in the comprehensive IPM program impacting 360 acres. 70% (252 acres) are using non-insecticidal mating disruption for pest management to control Oriental Fruit Moth and Codling Moth, lesser peach tree borer, peach tree

borer and 2015 dogwood borers with growers planning to use the dogwood borer pheromone in place of trunk insecticide sprays.

More than 50% insecticide applications in orchards are U.S. Environmental Protection Agency (EPA) designated “reduced risk” insecticides. Approximately 75% of all insecticide applications are with reduced risk, organophosphate (OP) alternatives (products safe for honey bees). This is dramatically changed from the 1990’s when over 75% of insecticides used in orchards were more toxic organophosphate, carbamate, or chlorinated hydrocarbon products.

Over the course of the project, fruit damage from insect infestation has been significantly reduced, largely because of season-long weekly pest monitoring and pest management recommendations provided by CCE’s entomologists and the Ag Stewardship program. A major highlight is that insect damage in orchards was reduced to less than 5% down from >22% in 2011.

An unusual development related to the decrease in use of insecticides to control orchard pests, Ag Stewardship Program has seen an increase in secondary or (new) pests not previously problematic. These pests include: European Saw Fly, Leaf Rollers and the San Jose Scale (previously thought not to exist on Long Island). Currently the Ag Stewardship Program and CCE entomologists are working to establish economic thresholds for these newly identified pests.

In 2014 there was a major outbreak of Fire Blight. This is a disease that destroyed hundreds of apple trees. In 2015 growers were better able to predict and prepare for the disease by using the RainWise weather stations and NEWA forecasting models. The outbreak was not related to the implementation of the project, but it is worth noting as it demonstrates the multi-use capabilities of the RainWise weather stations and CU NEWA programs.

Dr. Faruque Zaman, Associate Entomologist of CCE Suffolk, has been instrumental in contributing to the overall success of the project by meeting with each grower individually at the beginning of the season. Through this activity we were able to evaluate growers past year’s pest management records in relationship to the Ag Stewardship Program’s scouting, trapping and weekly reporting. He also provided growers, individual consultation and recommendations. He has been integral to the overall success of the project.

The tree fruit growers have become very invested and committed to continuing a partnership with CCE’s Ag Stewardship Program. This is due in large part to the technical on-the-ground scouting/trapping and support provided by the Ag Stewardship technicians. Also, each year the Entomologist and Ag Stewardship technician meet with each participating grower to analyze the cost/benefit of purchasing pheromones and more expensive environmentally friendly pesticides compared to less expensive sprays. At first glance it would appear more economically viable for a grower to use the less costly management practice; however, many times broad application sprays are proven to be less effective. After the grower evaluates amount of time he/she spends in Tyveck suits handling potentially harmful sprays and the reduction in productivity due to with long reentry time – growers have overwhelming opted to use the comprehensive IPM program this project has supported. Going forward, 100% of the growers we have worked with over the past 3 seasons are committed to continuing this program as a fee for service.

Other partners have included the Cornell University Research Specialists, Cornell University’s Hudson Valley Lab and Cornell University’s Pest Environmental Management Team. Individuals include: Art Agnello from the NYS Agricultural Experiment Station in Geneva, Susan Brown, Juliet Carroll, James Eve, Peter Jentsch, Craig Kahlke, Tessa Lessord, Kevin Maloney, Laura McDermott, James O’Connell, Harvey Reissig, Terence Robinson, Sara Villani, Anna Wallis, Kerrik Cox. These individuals conducted annual educational tours and workshops at each of the grower sites focusing on Integrated Pest Management practices and presented at the annual Long Island Agricultural Forum.

Goals and Outcomes Achieved

Our initial performance goals for this project were: a) to engage three tree fruit farms on approximately 165 acres in a comprehensive IPM demonstration project with the expectation that greater than 50% of pesticides used by the 3 participating orchards would be "low-input"; and b) participating growers would use the RainWise weather stations and Cornell University's Network for Environment and Weather Applications (NEWA) Program for forecasting pest and disease, thereby reducing and/or better managing insects and disease.

The results of this project and the work accomplished has far exceeded our initial goals and objectives. Eleven apple and five peach orchards have participated in the comprehensive IPM program impacting 360 acres. 70% (252 acres) are using non-insecticidal mating disruption for pest management to control Oriental Fruit Moth and Codling Moth, lesser peach tree borer, peach tree borer and 2015 dogwood borers with growers planning to use the dogwood borer pheromone in place of trunk insecticide sprays.

Going forward, 100% of the growers we have worked with over the past 3 seasons are committed to continuing this program as a fee for service.

Below is further breakdown of outcomes:

Scouting Analysis

Weekly scouting by the Ag Stewardship Program of all strategically placed insect traps for the following insects: Plum Curculio, Oriental Fruit Moth, Codling Moth, Oblique Banded Leaf Roller, Lesser Peach Tree Borer, Peach Tree Borer and Apple Maggot. Each grower was provided a timely report of pest thresholds for appropriate pest management strategies and all reports were included in the weekly CCE's Fruit and Vegetable Update that was sent electronically to all fruit growers.

Seasonally appropriate scouting for mites and aphids and participated with CCE entomologist in the end of season fruit evaluation, looking for damage done by trapped pests and European Apple Saw Fly, San Jose Scale, Tarnish Plant Bug, Stink Bugs and Stinging Insects.

Prior to 2012: Plum Curculio, Oriental Fruit Moth, Codling Moth, Tarnished Plant Bug, and European Apple Sawfly were the most significant insect pests in pome and stone fruits on Long Island. Together these insects were responsible for approximately 25% fruit damage. Plum Curculio was the most damaging pest in Long Island (LI) apples and peaches ranging between 5% and as high as 70% destruction in some orchards. Oriental Fruit Moth and Codling Moth, were two of the main reasons for broad application of insecticide use in tree fruit. Despite the sprays (4 to 7 applications/season) the two insects were responsible for between 3-7% fruit damage. Since then, the situation has improved significantly because of the on-farm pest identification, timely scouting and monitoring program, providing recommendations and effective control techniques such as the pheromone-mating disruption and using effective and reduced-risk pesticides / insecticides.

2013: Plum Curculio infestations reduced to 3.86%. Overall insect damage in LI orchards reduced to less than 5% down from >22% in 2011.

2014: Damage from Oriental Fruit Moth and Codling Moth reduced to less than 3% with the use of pheromone mating and reduction in insecticide application as low as 0 to 2 applications per season. More than 50% of insecticide applications are with the U.S. Environmental Protection Agency (EPA) reduced risk insecticides. 75% of all insecticide applications are reduced risk organophosphate (OP) alternatives (products safe for honey bees).

2015: Oriental fruit moth (OFM) damage was the lowest on record with just 0.25% in apples and 0.12% in peaches. Seven growers (with nearly 70% tree fruit acreage) on Long Island used pheromone-mating disruption in place of pesticide applications for control of oriental fruit moth,

codling moth and peach tree borers in their orchards. In the past three years, fruit damage from insect infestation has significantly reduced largely because of frequent pest monitoring and timely management of infestations. Participating growers continue to use reduced risk products with over 75% of all insecticide used being alternatives protecting pollinators including the honeybee. The Ag Stewardship Program and CCE's entomology program plan to continue working with LI tree fruit growers in a fee based tree fruit IPM program coordinated by the Ag Stewardship Program. Dr. Faruque Zaman, CCE's associate entomologist and I appreciate participating orchards commitment to environmental stewardship and to NYS Agriculture and Markets for supporting the comprehensive tree fruit IPM program.

Educational Programing

1) Since 2013 the Ag Stewardship Program, in cooperation with Dr. Zaman (CCE's entomologist), has provided the Long Island Agricultural Forum with an annual educational program updating LI's tree fruit growers with the most current pest problems and reviewing sustainable pest management practices. Growers have been given the prior season's scouting results to assist them in forecasting next season's pest problems.
2) Growers have been given individual tutoring on how to use their computers and access the RainWise weather station in their specific locale to monitor growing degree days, rain and humidity levels and the NEWA pest forecasting models to assist them in their decision making process.
3) Over the course of the grant, Dr. Julie Carroll, NY State's IPM coordinator, Cornell University's Tree Fruit IPM Coordinator and the Lead for the Network for Environment & Weather Application (NEWA) and Tim Weigle, CU NEWA IPM program, have provided 4 educational programs for the tree fruit industry at the LI Ag Forum and tree fruit twilight meetings. Their programs were geared toward teaching growers how to take advantage of pest forecasting models by using CU NEWA's network for more precise pest management practices.
4) 2015's On-Farm workshop at Wickham's Fruit Farm industry included representatives from Cornell University who came down to meet with LI growers. They demonstrated how to successfully implement mating disruption in orchards. Growers were introduced to new pheromone products, as well as the instruments used to hang pheromones in the fruit trees.
5) Over the course of the grant, annual orchard site-visits were made by regional extension, tree fruit specialists and entomologists: Peter Jentsch, Kerrik Cox, Dan Donahue, Steven Hoying, Art Agnello, who specialize in tree fruit production, pest, disease and overall orchard management. The team visited all growers participating in the Ag Stewardship IPM Program at least once. The CU Extension team scouted the orchards, spot checked for pests and disease and provided one-on-one instruction on pest best management practices.

Beneficiaries

Very clearly the results of implementing this project has impacted all of Long Island tree fruit growers. Any pest management suggestions and relevant pest outbreaks from participating fruit growers have been published in the weekly Long Island Fruit and Veg Update and goes out to all growers in Suffolk Co. Growers

Each year, the CCE entomologist and Ag Stewardship Technician have met with each participating grower to analyze the cost/benefit of purchasing pheromones and more expensive environmentally friendly pesticides compared to less expensive sprays. At first glance, it would

appear more economically viable for a grower to use the less costly management practice. However, broad application sprays are often proven to be less effective, thereby requiring multiple applications. After the growers evaluated the amount of time he/she spends in Tyveck suits handling potentially harmful sprays and the reduction in productivity due to with long reentry time – growers have overwhelming opted to use the comprehensive IPM program this project has supported. Going forward, 100% of the growers we have worked with over the past 3 seasons are committed to continuing this program as a fee for service.

Long Island has approximately 340 acres of orchards owned by 16 growers. CCE's Ag Stewardship IPM Tree Fruit Program has grown beyond our early expectations, now covering nearly 300 acres and working with 10 apple and 5 peach orchards. The Program runs in cooperation with CCE's Entomology Program. To produce quality fruit and maintain economic sustainability, growers depend on timely control of pests. The insect information we obtain from the weekly orchard-scouting program is published once/week in the LI Fruit & Vegetable Update and received by over 300 subscribers by email and fax.

On average, 30 tree fruit growers attend the annual LI AG Forum Tree Fruit Sessions. Participants include commercial growers, back yard growers and even nursery growers who have a small-scale production of fruit trees for sale. Our on-farm workshops and twilight meetings average 15 participants per meeting consisting of growers, managers and field workers. The monthly LI Agricultural News, a regional publication with articles related to the tree fruit IPM program reaches over 300 subscribers.

In addition, it is estimated 800 + hits are made on the Ag Stewardship's Facebook page, which features photos and updates on the tree fruit IPM program. Furthermore, the Ag Stewardship webpage on CCE's Website features IPM practices for the tree fruit industry and a direct link to all 18 RainWise weather stations with connection to Cornell University's NEWA pest forecasting models for distinct microclimates on both North and South Forks of Long Island.

Lessons Learned

Long Island's tree fruit growers have demonstrated their desire and appreciation for weekly scouting reports providing economic thresholds and the technical support. As stated above, going forward 100% of the growers are committed to continuing with the project as a fee for service program.

Something else learned was that pheromone disruption is not the silver bullet for insect control in orchards. A grower cannot be so dependent on pheromone disruption to ignore the other components of a comprehensive IPM program. To use pheromone disruption as the sole source of control without trapping and scouting can have dire consequences as it may not be as effective as anticipated.

An unusual development related to the decrease in use of insecticides to control orchard pests, the Ag Stewardship Program has seen an increase in secondary or (new) pests not previously problematic. These pests include: European Saw Fly, Leaf Rollers and the San Jose Scale (previously thought not to exist on Long Island). Currently the Ag Stewardship Program and CCE entomologists are working to establish economic thresholds for these newly identified pests.

In 2014 there was a major outbreak of Fire Blight. This is a disease that destroyed hundreds of apple trees. In 2015 growers were better able to predict and prepare for the disease by using the RainWise weather stations and NEWA forecasting models. The outbreak was not related to the implementation of the project, but it is worthwhile noting as it demonstrates the multi-use capabilities of the RainWise weather stations and CU NEWA programs.

Additional Information

- http://ccesuffolk.org/agriculture/agricultural-stewardship (CCE Suffolk County Agricultural Stewardship Program's website providing link to all RainWise Weather Stations, Information on the Ag Stewardship Program and IPM tree fruit program)
- http://cuaes.cals.cornell.edu/sites/cuaes.cals.cornell.edu/files/shared/2014AnnualReport_comp.pdf (Long Island Horticultural Research and Education Center, Page 14 of document features Dr. Faruque Zaman with information on Entomology and Ag Stewardship cooperation on IPM tree fruit program)
- http://www.lifb.com/ABOUT/FarmingonLI/tabid/242/Default.aspx (Long Island Farm Bureau: Farmers Going Green includes information on cooperation between CCE Entomology and Ag Stewardship on IPM tree fruit program)

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Project 6
Best Management Practices for Season Extension in New York

Project Summary

High tunnels (unheated soil-based greenhouses) have been widely adopted by New York specialty crop growers in the last decade. The state is experiencing a sharp increase now as USDA NRCS has funded 139 new projects in 2010-2012. High tunnels help growers increase profitability by enhancing yield, extending the growing season, protecting crops from weather extremes, and managing pests and diseases. However, with so many new tunnel operators there is a need for research and education to maximize the potential of the crops grown in this environment.

For this project we used a variety of methods to extend best management practices (BMP's) and the latest research results to growers. This included research trials, on-farm demonstrations, field meetings, farm visits, and formal educational events. In addition to reaching hundreds of growers through these efforts, the project team also worked with nine new high tunnel growers as case studies to track their progress and identify challenges to be addressed.

Through the course of this 3-year project we focused on key BMP's to increase grower satisfaction, production and profitability with their tunnels including site considerations, ventilation, spacing, crop and variety selection, training and pruning tomatoes, cucumbers in high tunnels and fertility management.

Project Approach

We used a variety of approaches to educate new high tunnel growers ways to improve efficiency, reduce problems, increase yield and quality and therefore increase their profitability.

Resources Developed

- Six Best Management Practices (BMP) factsheets on key topics to reinforce the production methods we encourage growers to adopt to increase quality, efficiency and yield. Distributed at all events, schools, field meetings, posted on websites. (see Appendix)
    - Site Selection
    - Spacing
    - Tomatoes for High Tunnels
    - Training and Pruning Tomatoes
    - Leaf Mold in High Tunnel Tomatoes
    - Cucumbers for High Tunnels
- Two 8-minute video clips on grafting, available on YouTube
    - Why Graft: https://www.youtube.com/watch?v=P1tGxe_tQ-0&list=PLMxaHBxUI9qaCO-yXzztmb6TLzRVGxyo0
    - How to Graft, step by step: https://www.youtube.com/watch?v=08YfqCpL3po&index=2&list=PLMxaHBxUI9qaCO-yXzztmb6TLzRVGxyo0
- A 30-minute webcast by Judson Reid, *Tomato Diseases Favored by High Tunnels*, http://www.plantmanagementnetwork.org/edcenter/seminars/tomato/hightunnelgreenhouses/default.asp

Group Trainings, Field Meetings

- 6 day-long High Tunnel Schools around the state provided in-depth learning to 245 growers
    - Program focus was on the BMP's (Best Management Practices) with presentations by the project team and experienced high tunnel growers
    - Featured peer to peer learning and experience sharing
- A full session at the Empire State Producer's Expo in Syracuse in January '13 and '15 for a total of 86 growers broadened the reach of the project. Training & Pruning and Tomatoes best suited to high tunnel growing were the key topics.
- Summer field meetings at farms with tunnels in production provided hands-on and peer to peer learning opportunities. 279 growers attended the 13 field meetings over the course of this project.
    - We had originally intended our case study growers to host the field meetings but the project team ended up choosing other farms to host the meetings to better illustrated the BMPs we promote. Our case study growers each attended at least 1 field meeting or indoor class and joined the discussion about lessons learned from their participation in this project.
    - BMPs such as ventilation, fertility, spacing, pruning and training are best understood when seen in the field at these meetings.
- A 2-day training for 42 field staff of Cornell Cooperative Extension and NRCS (Natural Resources Conservation Services, the USDA agency providing grants for tunnel purchases) honed staff skills across the state in advising new tunnel growers. One day of lecture and discussion, a second day of field visits to 3 different operations.

Grower Schools Summary								
2/7/2014	Grower meeting	CVP and Chautauqua Produce Auction	Judson Reid	High Tunnel tomato update	0.5	Clymer, NY	30	Indoor meeting
2/25/2014	Grower meeting	CVP and Orleans Produce Auction	Judson Reid	High Tunnel tomato update	0.5	Albion, NY	30	Indoor meeting
12/2/2014	High Tunnel School	CVP and ENYCHP	Judson Reid, Amy Ivy, grower panel	Best management practices for high tunnels	5	Bath, NY	40	Indoors
12/4/2014	High Tunnel School	CVP and ENYCHP	Judson Reid, Amy Ivy, grower panel	Best management practices for high tunnels	5	Millbrook, NY	45	Indoors
12/12/2014	Grower meeting	Seneca Produc	Judson Reid	Vegetable Variety selection and Success with Tunnels	2	Romulus, NY	30	Indoors
1/21/2015	Expo HT session	NYS Veg Growers Assoc, CCE	Judson Reid	High tunnel BMPs	0.5	Syracuse, NY	40	Indoors
2/4/2015	Erie County High Tunnel School	CVP	Judson Reid, Amy Ivy	Crop Economics and HT Tomato Disease Mgt, Training and Pruning Tomatoes	1.5	East Aurora, NY	30	Indoors
					total school attendees		245	

SCBG Grower Field Meetings Summary								
Date	**Event**	**Host Group**	**Lead Speaker**	**Title or Subject**	**Hours of SCBG project material**	**Location**	**Approx # in Audience**	**Field or Inside Meeting?**
5/6/2014	Field meeting	Fledging Crow	Neil Mattson	Testing irrigation water for pH and alkalinity	1	Keeseville, NY	14	Field
7/9/2014	Open House - on Farm	Cornell Willsboro Research Farm	Amy Ivy	Review of ongoing projects in research tunnels	0.25	Willsboro, NY	40	Field
7/17/2014	Field meeting	Steuben CCE	Stephanie Mehlenbacher	High tunnel BMPs	1	Cohocton, NY	6	Field
7/28/2014	Field meeting	Cornell Willsboro Research Farm and Carriage House Garden Center	Judson Reid, Amy Ivy, Michael McCauliffe (Grower)	Leaf mold, cucumber training systems, LM resistant determinate tomato varieties	2	Willsboro, NY	26	Field
7/29/2014	Field meeting	CCE Canton Learning Farm	Judson Reid, Amy Ivy	Leaf mold, tomato training methods,	0.75	Canton, NY	22	Field
7/8/2015	Open House - on Farm	Cornell Willsboro Research Farm	Amy Ivy	Update on projects in research tunnels	0.25	Willsboro, NY	45	Field
7/8/2015	Field meeting	CVP	Judson Reid	Season Extension for Organic Vegetable Farms	3	Eden, NY	15	Field
7/9/2015	Field meeting	Journey's End Refugee Program	Judson Reid	High Tunnel technical training	2	Buffalo, NY	20	Field
7/14/2016	Field Meeting	CCE Steuben Co	Stephanie Mehlenbacher	High tunnel BMPs	1	Campbell, NY	8	field
7/29/2015	Field meeting	CCE Canton Learning Farm	Judson Reid, Amy Ivy	Best management practices for high tunnels	2	Canton, NY	25	Field
8/6/2015	Field meeting	CVP and ENYCHP	Judson Reid, Crystal Stewart	Best management practices for high tunnels, testing water for alkalinity and pH	2	Kinderhook, NY	12	Field
8/6/2015	Field meeting	ENYCHP	Judson Reid	Fertility and Water Management for High Tunnel Tomatoes	2	Stuyvesant, NY	20	Field
8/24/2015	Field meeting	Shady Grove Farm	Judson Reid, Crystal Stewart, Amy Ivy	Best management practices for high tunnels	2	Schuyler Falls, NY	26	Field
					total field mtg attendees		**279**	

One-on-one Consultations

- In 9 case studies we worked closely with individual growers over 3 summers as they implemented recommended practices best suited to their particular operations
- Project staff advised over 80 individual high tunnel growers across the state, providing guidance and explaining or demonstrating our BMP's appropriate for each specific situation

Research Projects

We conducted several research projects at the Cornell Willsboro Farm in northeastern NY and on a cooperating farm in western NY to provide data for staff and growers to use in devising best management practices. See Section 7 for full research reports.

Research Projects in Willsboro

- Winter greens trial – 2013
- Grafting tomatoes - 2013 - determinate varieties,
- Grafting cucumbers – 2013
- Training cucumbers - 2014 - single leader vs trellis systems
- Winter Salanova lettuce trial – 2015

Research Projects in Penn Yan

- Determinate variety trial for resistance to leaf mold – 2013
- Determinate tomatoes, grafted vs ungrafted 2014

Project Team Staff:

Amy Ivy - Vegetable Specialist, Eastern NY Commercial Horticulture Program

Judson Reid - Vegetable Specialist, Cornell Vegetable Program

Stephanie Mehlenbacher - Horticulture Educator, Cornell Cooperative Extension Steuben County

Elizabeth Buck, Cordelia Hall and Nelson Hoover – Field Technicians, Cornell Vegetable Program

Michael Davis, Farm Manager – Cornell Willsboro Research Farm

Goals and Outcomes Achieved

Outcome #1

We realized in 2014, after our trials, that grafting was not a realistic outcome for this project. The benefits of grafting are seen after tomatoes have been grown in the same soil for several years because by then soil borne diseases have begun to build up and the vigorous, disease resistant rootstock helps the plants tolerate the diseases. However, our trials have shown that in the early years of tunnel production, the benefits of grafted plants are not realized. Grafting is stressful and the scion (top section of the plant) becomes more rampant and harder to keep properly pruned and trained. Grafting cucumbers is an extremely delicate process in which we had very poor results. In short, grafted plants are not recommended for new growers and those growers are the focus of this project.

We did widely distribute our detailed fact sheet on how to graft tomatoes. At our 6 winter High Tunnel schools, 32% of attendees responded that they would try growing grafted tomatoes for the first time the following season. (See the research reports in the Appendix for details on our trials.)

For additional resources we created two 8-minute videos on grafting by Judson Reid for interested growers. One focuses on the advantages of grafting and the other shows the step-by-step process. These in-depth, visual discussions will enable growers to understand the process and decide if it fits into their production system. As of September 2015, these videos have had almost 20,000 views.

The first explains the advantages of grafting: https://www.youtube.com/watch?v=P1tGxe_tQ-0&list=PLMxaHBxUI9qaCO-yXzztmb6TLzRVGxyo0

The second shows the step-by-step process:

https://www.youtube.com/watch?v=08YfqCpL3po&index=2&list=PLMxaHBxUI9qaCO-yXzztmb6TLzRVGxyo0

Revised Outcome #1

Our revised focus for the first outcome became explaining, illustrating and demonstrating the benefits of our BMP's to convince growers to adopt them as part of their crop production methods. In most cases, growers adapted their management to include these practices gradually, incorporating one or two each year, and have been pleased with the results. For example, growers reported greater efficiency working in tunnels with adequate spacing, increased satisfaction for staff working under these conditions, an increase in yield each year as they fine-tuned their pruning and training skills, less loss to leaf mold by choosing disease-resistant varieties, markedly better plant growth and yield once drainage issues were corrected, and increased fruit set in cucumber when properly pruned and parthenocarpic varieties were chosen.

In some cases an unforeseen challenge, such as record rainfall early in the season that flooded the tunnel, focused their attention to that particular issue. In other years, an outbreak of brown leaf mold prompted a shift to ordering leaf mold resistant varieties from our list the following season.

In the evaluation/surveys distributed at all 6 of our winter High Tunnel Schools over two years, where we explained and discussed these BMP's, we had the following responses (144 responses total from 228 attendees):

- 85% will start training and pruning their tomatoes sooner than they have been;
- 65% agreed they need to ventilate their tunnel more than they have been;
- 48% said they would try the training methods we explained; 29% who already do so said they would work on their technique;
- 75 % will choose leaf mold resistant varieties for the upcoming season.

Best Management Practices (BMPs) Impacts (see Additional Information for the full-text documents)

Siting and Structures

This was very useful at our High Tunnel schools and grower meetings for those who were still planning on getting started or adding another tunnel to their operation. Snow load, sun and

wind exposure, overall drainage of the location, soil type of the tunnel, availability of water for irrigation, are all key considerations buyers need to keep in mind when deciding.

Growers shared their experiences about failures of some cheaper tunnel designs and materials as well as their satisfaction with other types and brands of tunnels. Experienced growers encouraged new growers to shop for quality rather than cheapest price. Growers value and believe first-hand experiences and exchanges such as these.

Tomatoes for High Tunnels

Tomatoes are the number one crop for high tunnel production in New York and an excellent first crop for new high tunnel growers. Therefore, our focus throughout this project has mostly been on tomatoes, cucumbers and greens to a lesser degree.

The choice between determinate versus indeterminate types of tomatoes has an impact on the harvest period and amount of time required by the grower to manage them. This BMP helps growers decide which types of tomatoes are best suited to their market and growing styles. Some markets pay a premium on heirloom tomatoes while others value perfect fruit more highly. By understanding their options, growers can make the best decisions for their operation to maximize yield, price and/or profitability.

Spacing

Many growers, new and experienced, struggle with proper spacing of the plants in their tunnel. The tendency is to pack in as many as possible. Through one on one consultations, site visits, grower field meetings and winter schools, we reminded growers repeatedly that more plants does not necessarily mean more yield.

Growers who increased their spacing reported greater ease in training, pruning, harvesting, scouting and if necessary, spraying the plants. By seeing how other growers lay out their tunnels and hearing others comment on their increased satisfaction with proper spacing, growers have increased their own spacing with good results.

Training and Pruning Tomatoes

Along with spacing, proper training and pruning is critical to success and satisfaction in growing tomatoes in high tunnels. Tomatoes can grow rampantly under the ideal conditions a tunnel provides. However, that growth must be controlled to make the crop manageable for the grower. This BMP illustrates, through pictures and descriptions, our suggested methods of pruning and that training and has been a valuable tool in explaining the procedure to growers. It is particularly helpful on farm visits to reinforce our pruning and training suggestions and to give the growers a reference they can refer to later as they master the technique.

Of all the topics we covered at our winter schools, training and pruning had the greatest response:

- 85% reported they needed to get started training and pruning their plants earlier, and keep at it;
- 48% reported they would try our suggested methods for single leader training on indeterminates and 27% said they already do this but would work on their technique;
- 43% said they would try our suggested methods for stake and weave training for determinates and 31 % said they already do this but would work on their technique.

Leaf Mold on Tomatoes

Most common tomato diseases (early blight, Septoria leaf spot, bacterial diseases) are less prevalent in high tunnels because the leaves remain dry. However, brown leaf mold, *Passalora fulva*,

is actually enhanced by the protected conditions. Brown leaf mold is seldom seen in outdoor field conditions but is very common in tunnels. The only effective way to manage leaf mold is by choosing resistant varieties. Fungicide sprays are limited in tunnels and are ineffective on this particular pathogen.

We trained growers to identify the early and later symptoms of this disease and then provided a list of resistant varieties. Leaf mold is often confused with other leaf spots so our BMP includes photos of look-alike problems to enable growers to properly identify the damage. Heirloom varieties are popular with many growers but all are susceptible to leaf mold. We encourage growers to plant several varieties and include at least some with leaf mold resistance, to help them realize a profitable yield even if this disease appears. Once a tunnel has leaf mold it returns every year thereafter.

Cucumbers for High Tunnels

Although tomatoes are the top crop for high tunnels, especially for new growers, cucumbers are the next most profitable. In addition, because they are unrelated to tomatoes, they do not share the same diseases, which makes them an excellent crop for diversified production.

We educated growers about few key factors for success with cucumbers in tunnels including:

- Training the plants vertically to save space, increase air circulation to reduce disease pressure, and develop clean, straight fruit;
- Choosing parthenocarpic varieties that do not need pollination;
- Choosing powdery mildew resistant varieties to increase productivity and reduce the cost and time associated with spray applications;
- Recognizing spider mite infestations at the earliest stages for better control, especially if bio-control measures are chosen.

Other BMPs

Irrigation and Drainage Issues, Ventilation, and Fertility are additional BMPs that we discuss with growers in the various programs, schools, newsletters and farm visits throughout this project. Each of these topics is complex and depends on many factors that are particular to each operation, which makes them difficult to condense into a concise document.

At our winter schools, 65% of the respondents said after hearing our discussion and grower comments that they realized they need to ventilate their tunnel more than they have been. Growers tend to keep their tunnels closed up too much, trapping moist air inside. On farm visits, we assessed their ventilation in real time and discussed ways they could amend or better manage their tunnels to allow for increased air circulation.

We visited several tunnels where the drainage at the site was inadequate. During a rain event, a large amount of water flows off the tunnel along the sides. If this water cannot move away quickly it tends to seep into the tunnel, flooding the crop and creating ideal conditions for long term root diseases. We advised these growers how to ameliorate their situation and have used these experiences to caution future tunnel buyers to consider these factors carefully when deciding the location of their tunnels. Spending some time during the construction of the tunnel to offset any potential drainage problems is well worth the investment.

Finally, a 30 minute webcast by Judson Reid, *Tomato Diseases Favored by High Tunnels*, explains our BMPs to help reduce disease pressure in tunnels, and it answers many questions about high tunnel production that we have received from new growers. By having this as a resource, growers can refer back to it as often as necessary to fully understand the principles we addressed in

this project.
http://www.plantmanagementnetwork.org/edcenter/seminars/tomato/hightunnelgreenhouses/default.asp

Outcome #2

Our case studies, conducted with nine growers over three growing seasons showed a variety of impacts and lessons learned. By working closely with these growers, we were able to understand their particular challenges and help them adapt those BMPs that would best help them be more successful.

A short summary of each case study is included in the Additional Information section. The chart below gives an overview of areas in which each grower made improvements over the course of this project.

A snapshot of progress made in key focus areas

	Grower A	Grower B	Grower C	Grower D	Grower E	Grower F	Grower G	Grower H	Grower I
Ventilation				✓	✓✓	✓	✓		✓
Pruning & Training	✓✓	✓✓	✓✓	✓	✓	✓		✓	✓
Water Mgt, Irrigation and Drainage	✓✓	✓		✓		✓✓	✓✓	✓	✓
Fertility Mgt	✓		✓		✓✓	✓	✓		✓✓
Pest & Disease Mgt			✓	✓✓	✓			✓✓	✓✓
Crop Choices & Timing		✓✓	✓	✓✓	✓	✓	✓✓		✓
Variety Selection	✓	✓	✓✓	✓				✓	✓

Some specific accomplishments and highlights from our case studies:

- One grower had been watering his tunnel until it temporarily flooded each time. We demonstrated to him how to regulate his water to avoid drowning crop roots and wasting water. He changed his watering habits and improved drainage at the end of his tunnel.
- One grower set two determinate plants in each planting hole in his first year, thinking it would bring twice the yield. The plants became a tangled mess. The second year he followed our spacing guidelines and saw a greater yield per plant, averaging an increase in yield of 5.06 lbs. per plant

  Note: This increase of 5.06 lbs./plant from 405 plants sold at $3/lb. equals an increase in gross profit of $2,049.30 from this one tunnel.

- Two growers had problems with rain water overflowing into their tunnels which stunted the crop to the point of failure. Our advice on diversion drainage and soil amendments enabled them both to have a full crop the following year. This improved drainage also reduced root rot disease pressure from Verticillium wilt.
- One grower made significant improvements to his fertility program and was able to keep his crop producing after the first set of heavy fruit. By doing so he saw a 20% improvement in his yield over the year prior when he lost an average of 1.5 flower clusters per plant to poor nutrition.
- One grower mixed together her determinate and indeterminate tomatoes the first year, which made it impossible to properly train and prune them. She learned first-hand the importance of paying attention to this important detail and was 100% more satisfied with the crop the following year.
- Two growers realized a traditional high tunnel crop of summer tomatoes did not fit into their farming practices. One, a large orchard, decided the best crop their tunnel could produce for them was an early crop of summer squash after which they turned their attention to their orchard crops. The other grower realized that the fall agri-tourism market is what they want to focus on. So rather than push for an early crop, she planted a late summer tunnel crop of various vegetables and flowers that appeal to her customers' interests. By accepting these non-traditional crop systems, each grower was able to avoid wasting time and resources on crops they didn't have a market for. Their satisfaction with their tunnels has increased an average of 80% as a result.

Advice from case study growers for other growers:

- Know your market – timing (when are your peak sales weeks), product (heirloom vs picture-perfect), figure out where will you will sell your product before you get started.
- Visit other growers' tunnels before deciding what size and brand to buy.
- Don't go cheap on materials, especially where weather is severe.
- Anchor the tunnel well, especially in windy locations.
- Ensure good drainage inside and outside the tunnel.
- Set up a drip irrigation system – not that complicated and well worth the minor cost.
- Most growers like the extended straight sides – better ventilation from the larger opening and more room for taller crops along the sides.
- Provide adequate spacing and keep plants trained – increases yield and also worker satisfaction. A jungle of stems makes pruning, spraying, harvesting unpleasant.

We had originally intended our case study growers to host the field meetings but in most cases (except for Growers C and E) the project team ended up choosing other farms to host the meetings to better illustrate the BMPs we promote. Our case study growers attended at least one field meeting each and joined the discussion about lessons learned from their participation in this project.

Our expectation that our case study growers would increase their square footage of high tunnel production within the project timeframe was unrealistic. Only 1 case study grower added an additional 96' high tunnel during this period, for an increase in gross revenue of at least $12,000.

One other definitely plans to add another tunnel when he retires within the next few years. All 9 growers reported more efficient use of their tunnel space as a result of this project, and increased satisfaction working in their tunnels. Better training and pruning make a tunnel of tomatoes much easier to work in compared to the rampant, tangled growth they struggled with before adopting our BMPs for spacing and training. In Steuben County, we know of 2 tunnels that growers put up directly as a result of speaking with 2 of our case study growers. So although the case study grower didn't add another tunnel in this time frame, more tunnels were put into production as a result of this project. The total gross revenue realized by the participating growers is $49,302. The chart below summarizes the increase in gross dollars realized by case study participants and where they shared their learned expertise with others.

Grower	**Increase in gross dollars**	**Notes**	**Shared learned expertise with others**	**Comments**
A	$2,050	From year 1 to year 2	Spoke to growers informally at winter high tunnel schools in Dec '13 and grower discussion in '15	By increasing yield 5.06 lbs/plant through better spacing and pruning
B	$0	See comments	Spoke to growers informally at winter high tunnel schools in '13 and '15, summer field meetings in '14 and'15	Scaled production down to fit their farm, economized on labor, materials, wasted product. So no increase was seen but losses were avoided.
C	$4,152 $12,000 $4,500	year 2 year 3 year 3	Hosted field meetings each summer in July: '13 and '14	20% increase in yield by using leaf mold resistant vars ($4152 increase) Took 2 misc. tunnels and put them into full production, 1 of cucumbers, and 1 of tomatoes. Baseline data not available, took estimated gross yield of intensive tunnels, divided by half for increase over previous crops. $12,000 increase in the 2nd tomato tunnel, $4500 increase in the cucumber tunnel.
D	$3,700	from year 1 to year 3	Talked to new growers, one couple put up a new tunnel after talking with him.	1st year plants kept too cold, bad year. Year 2 crop in a month earlier. Pollination improved with honeybees, better training, foliar nutrient testing. 48' long tunnel, 200 plants/tunnel. Crop yield increased 100% from year 1 to year 3. 200 plants @15 lbs in year 3 = 3000# @$2.50/lb= $7500 in year 3. At

				increase in gross revenue of at least $3700 over year 1.
E	$3,900		’14 hosted small field mtg. In ’15 spoke at a field mtg in Campbell with 8 people.	Reported a 300% increase in quality due to better trellising, mgt –$.50/lb increase in value. Improved from 230 plants yielding 15 lbs @$2.00 to 230 plants yielding 18 lbs @$2.50 From $6900 to $10,800
F	$5,500	48’ tunnel	Shared his experiences with others.	Improved soil compaction and tilling practices, monitored nutrients, better watering, pruning, and training. Average yield increase of 10 lbs/plant from year 1 to year 3. 220 plants
G	$0	see comments		He improved early season wet conditions, changed crop timing and crops to fit into apple schedule. He decided to cut back on crops in tunnel in order to focus on apples, so he grows mostly zucchini and summer squash in tunnels now.
H	$11,000	22’x96’ tunnel	These brothers have learned a lot and have come a long way. They have shared their experiences with other growers.	Had Pythium and flooding year 1, almost a total loss. Each year has gotten better. Year 3 was very good. 440 plants increased yields from 5 lbs/plant in year 1 to 15 lbs/plant average in year 3. 10 lb/plant increase at $2.50
I	$2,500	96’ long tunnel		Increased yield by 1000# from ’14 to ’15 @$2.50
Total increase in gross revenues	**$49,302**			

Beneficiaries

- 279 growers attended our field meetings located on farms with high tunnels for hands on learning.
- 245 growers attended our winter high tunnel schools or other indoor classes.
    - 85% reported they needed to get started training and pruning their plants earlier, and keep at it;
    - 48% reported they would try our suggested methods for single leader training on indeterminates and 27% said they already do this but would work on their technique;

- 43% said they would try our suggested methods for stake and weave training for determinates and 31 % said they already do this but would work on their technique.

- We estimate 122 attendees (half) will increase yields and gross income by $5,000/year for a total increase of $61,000 (a conservative estimate).
    - Based on the assumption that about 50% of the 245 attendees make some improvements to how they manage their tomato crops, they should see an increase in yield of 5 lbs per plant. With a low average number of plants per tunnel at 400, 400x5lbs = an increase of 2000 lbs. At an average price of $2.50/lb that is a $5000/year increase for 122 attendees.
- At least 400 hard copies of our 6 BMP factsheets have been distributed at field meetings and winter schools
- Growers considering purchasing a high tunnel for the first time learned how to compare various tunnel structures, Quonset versus gothic roof styles, size considerations for cropping and year round management, and site considerations in order to avoid costly mistakes.
- New high tunnel growers learned how to grow tomatoes and cucumbers, two of the most profitable crops for high tunnels.
- Experienced high tunnel growers were not the target audience for this project but those who attended our schools and field meetings learned to fine tune some of their practices such as training indeterminates to a single or double leader, stake and weave training systems for determinates and new varieties suitable to high tunnel production and resistant to leaf mold.
- Our nine case study growers honed their skills and increased productivity and satisfaction as a result of our frequent visits and consultations to resolve their challenges.
- 96% of the 228 high tunnel school attendees said the program gave them new factors to consider in choosing a high tunnel. We presented options for their consideration: research, field staff experiences working with many growers and individual growers themselves. It was then for each person to decide what would work best for their situation.
- Our case study growers saw an increase in production of about 5 lbs./plant. At an average of $3/lb. and 400 plants per tunnel, that is an increase of $6,000 in sales from the same space.
- Most growers who have compared growing tomatoes in the field with under high tunnels appreciate the longer season, increased yield, reduced disease pressure and protection from weather extremes.
    - In most years, two common leaf diseases, Septoria leaf spot and early blight weaken plants grown in the field and reduce production. In addition these field tomatoes are exposed to cool fall temperatures that drastically slow or shorten the production season. High tunnels keep tomato leaves dry so these diseases are rarely seen in tunnels to any extent. And when the tunnels are closed up at night in September tomatoes inside continue to produce into October, even in the northern regions of New York State.
- Staff who attended our 2-day school/in-service learned about our BMPs and other resources for their use to distribute to growers with whom they work. 42 Cornell and Cornell Cooperative Extension Field staff and 5 NRCS (Natural Resources Conservation Service) staff who are funding high tunnels attended.

Lessons Learned

High tunnels alone don't make a grower money -- it is how the grower manages their tunnels that makes the difference. New growers often have an idealistic approach and can be reluctant to adopt some of the more intensive practices we suggested through our BMPs. Including experienced growers in the process is an excellent way to persuade newer growers to try some of our suggestions.

There is no one way to manage a tunnel -- this is not a cookie-cutter procedure. We provided a range of options to help growers be more productive and profitable, but they have to choose which will fit best for them. Some growers are more resistant to change or to try new approaches than others.

Winter meetings work well for attendance since more growers have time to get away and there is time to go in-depth into our research results and more detailed explanations. But seeing an actual tunnel in production and talking to the grower who manages that tunnel is powerful. Include both types of learning opportunities and include experienced growers as speakers at the winter tunnel schools.

The qualitative result of farmer satisfaction from using tunnels is harder to measure, but very real. Some find great satisfaction from their tunnels; however others can't keep up or find them too challenging to manage. Satisfaction definitely improves during periods of intense weather (e.g. a cool, rainy June where field tomatoes languish while the tunnel tomatoes flourish).

A significant challenge we face is in getting growers to keep detailed records. Some are excellent at this while others feel too busy to invest the time. Some start out the year with good intentions, but by August when everything piles up, record-keeping can be the first task to slide. Tomatoes are harvested a couple times each week over a period of many weeks and most growers grow several varieties. With so many variables, data can be cumbersome to properly track. Once a grower accepts the value of these data to their own operation they are more motivated to follow through, but project staff can only push so hard.

A future project could focus specifically on how to help growers adopt or design a record keeping system that will fit into their farm practices. These records can provide valuable information as growers determine which crops are profitable and decide which to discontinue.

Overall, the project staff enjoyed working more intensively with individual growers over the 3-year project; seeing them progress, and helping them identify and deal with their challenges. Some challenges we can help them meet such as keeping tomatoes well trained and properly watered. Other challenges such as family dynamics, poor location and weather extremes may not be possible to correct; however, acknowledging these challenges can help growers focus on areas where their efforts will see results. Summarized details about each grower are in the following section.

Additional Information

This section includes:

- Summary of the 9 Case Studies
- Research Reports
- Full copies of each BMP (Best Management Practice) factsheet
- Additional photos

Websites with information from this project and more:

Cornell University's High Tunnel Website (currently under revision):
http://www.hort.cornell.edu/hightunnel/

Cornell Vegetable Program Website:
https://cvp.cce.cornell.edu/

Eastern New York Commercial Horticulture Program Website:
http://enych.cce.cornell.edu/

Cornell University's Vegetable Crops Website:
http://www.vegetables.cornell.edu/

Summary of 9 Case Studies

Grower A

Challenges:
spacing, had 2 determinates per hole; training, a tangled jungle; watering to the point of flooding; weed control; fertility, used same product all summer; field varieties of tomatoes

Improvements Made:

- Increased spacing to our recommendations with excellent yield
- Perfected stake & weave for determinates, single leader for indeterminates, mesh trellis for cucumbers
- More attention to timing of trickle irrigation to avoid puddling and excessive amounts
- Black plastic mulch to control weeds
- Adjusted fertilizer to address low potassium from late July on
- Changed varieties to greenhouse varieties, is especially pleased with the production on Red Deuce
- Increased yield of 5.06 lbs./plant from 405 plants sold at $3/lb. equals an increase in gross profit of $2,049.30 from this one tunnel.

Grower B

Challenges:
No prior experience; no big market in place for the product; farm focused on agri-tourism – corn maze, pumpkins, petting zoo, wagon rides so vegetables are a minor priority; training and pruning; variety and crop selection and layout; weed control; timing; hand watering with hose

Improvements made:

- Acknowledged agri-tourism was primary so adjusted crop schedule for later season production when most customers were coming to the farm
- With our hands-on coaching, much improved pruning and training technique, better understanding of determinate versus indeterminate growth habits
- More thought into variety selection including practical aspects such as disease resistance and vigor

- More planning on layout to make the best use of the space
- Installed ground cloth for weed control, a huge improvement in labor and satisfaction
- Installed drip irrigation system

Grower C

Challenges:

Spacing and training – tomatoes are extremely crowded, tunnel is a jungle by mid-July, challenging to work and harvest in, very poor air circulation through the plant canopy; fertilizer system in place but not well monitored; K deficiency; using old varieties, leaf mold reduced crop by 25%; poor fruit set on cucumbers due to pollination and training; overhead watering

Improvements made:

- Increased spacing in the row and between rows, stays on top of training and pruning now. Huge improvement in worker satisfaction, productivity and crop yield
- Using foliar testing to fine tune fertility to avoid K deficiency. Still a challenge but a big improvement, foliar applications of potassium sulfate according to test results are helping.
- Using leaf mold resistant varieties and varieties suited to tunnel production for greater yield, better fruit quality. His customers prefer perfect fruit over heirloom varieties and he has changed to meet that demand. Changed to parthenocarpic cucumbers that don't need pollination and perfected training plants to single leader. Installed drip irrigation to keep leaves dry, increase labor efficiency and deliver plenty of water to the crop

Grower D

Challenges:

Grew only 1 variety of tomato, pollination problems in tomatoes, tunnel kept too cool in early summer slowed ripening; got plants in late and missed early crop; keeping up with pruning and trellising

Improvements made:

- Set out tomatoes earlier the following season and used row cover and supplemental heat at first. Crop came in a month earlier than previous year.
- Pollination improved when honeybees were added to the farm
- Stayed on top of pruning and training, learned that doing a little a couple times a week is better than letting it get out of hand and trying to catch up
- Soil and foliar testing for nutrient management, made an additional application of Epsom salts to address Mg deficiency

Grower E

Challenges:

Late spring frost in '13 destroyed most of the crop, replanted crop was delayed; low fertility; training and pruning; inadequate ventilation for warmer weather; trellis material not strong enough

Improvements made:

- Installation of gable end vents and fans has improved air circulation
- Watching closely for frost warnings in spring then using row covers over young plants and closing up tunnel on cold nights has reduced loss and extended sales later in the season as well

- Improvements in keeping up with training and pruning tomatoes, keeping up with it better, switched to rot-resistant twine
- Soil testing before planting and foliar testing during the season has improved fertility
- Better training has improved air circulation through the plants and more ventilation during warm weather is reducing late summer disease problems.
- Grower reports a 300% increase in quality since the first season

Grower F

Challenges:
Soil compaction from over-tilling; proper pruning and training; soil pH too high; irrigation management

Improvements made:
- Changed from too much power tilling to reduced tillage with broad fork and wheel hoe. Looser soil, better root growth and water infiltration
- Planted buckwheat cover crop to help with compaction
- Monitoring soil fertility and pH before planting
- Fine-tuned pruning and training
- Closer attention to watering, checks under plastic mulch to monitor moisture levels in soil

Grower G

Challenges:
Heavy rains first year flooded tunnel and crops; overhead watering keeps leaves wet; not enough space between rows; weeds; ventilation; aphids and powdery mildew; late crops like tomatoes are not fitting well into his orchard-based operation

Improvements made:
- Diversion ditches installed outside tunnel to redirect heavy rain, avoid over-saturating crops
- Drip irrigation installed to keep leaves dry, reduce disease pressure
- Increased spacing for better air movement, less competition between plants, reduced humidity which helps reduce powdery mildew
- Earlier detection of aphids and better timing of applications helps reduce pest population
- Acknowledged that the orchard crops are primary and adjusted high tunnel crops to early summer squash to fill a niche. An example where growers need to tailor their tunnel crops to fit their farming operation

Grower H

Challenges:
Flooding in tunnel first half of the season and subsequent pythium (root rot disease) outbreak; excessive fungicide application made damage worse; low fertility; two-spotted spider mite outbreak in year 2; blossom end rot in year 1 from inadequate irrigation

Improvements made:
- Diversion ditches installed and reduced flooding
- Grower education on pests and diseases; earlier identification and appropriate actions helped keep pests and diseases to lower levels
- Varieties chosen for vigor and disease tolerance helped reduce pressure
- Drip irrigation management is better managed to alleviate blossom end rot

- Pre-plant fertility adjustments were made, a fertigation system would help in-season

Grower I

Challenges:
Lack of prior experience; high soil pH and high alkalinity and pH of irrigation water; low fertility caused blossom loss in year 1; botrytis, gray mold and Verticillium wilt disease problems;

Improvements made:
- An eager learner, this grower has made remarkable improvements to his production system
- Adjusted soil pH with sulfur, acidified irrigation water to correct alkalinity and pH there
- Learned to interpret soil and foliar nutrient tests and adjust fertigation according to those test results
- Chose disease resistant varieties to deal with soil borne problems.
- Learned to identify diseases at the earliest stages to begin control measures in time, big improvements in application methods and timing, and product selection

Winter greens trial – Cornell Willsboro Farm – Nov 2012-Feb 2013

All-star lettuce mix and *Winter Density* bibb lettuce were selected to test crop responses with and without low row covers. The two treatments were:
- Beds with low row covers
- Control beds without row cover

A randomized complete block design was used with three replications.

Evaluations: All beds were visually scored for growth performance on January 14, 2013, and again on February 15, 2013. A rating system of 0-10 was used for each planting, with 10 denoting the most productive growth and 0 indicating there were either no edible plants parts or the plants were all dead.

Results and Discussion:

Weather: Willsboro experienced seasonable to mild temperatures throughout November and December of 2012, and extending into the middle of January 2013. No temperature readings below zero Fahrenheit were recorded during the first ten weeks of the experiment. A cold, high pressure cell covered the Willsboro area at the end of January and the air temperature inside the high tunnel dropped to -10 degrees Fahrenheit at 6:00am January 24, and -8 degrees Fahrenheit at 6:00am on January 25. The below zero temperatures at the end of January 2013 stressed many of the trial plants, and as a result the plot ratings for some of these crops were very different after the cold snap compared to the pre-cold snap ratings (Tables 6&7).

All-star lettuce mix: The lettuce mix starts were in the seedling trays for over five weeks prior to the transplanting date, and the plants were of harvestable size at transplanting time (November 11, 2012). As a result, a cutting was taken from all the lettuce mix trays prior to transplanting. Lettuce mix growth after transplanting was greater in the row cover beds compared to the control beds, but it was not enough to generate a second cutting by the January 14, 2013 evaluation. *All-star* growth really started to pick-up after January 14, particularly in the beds with low row covers (Table 7), such that a second cutting could have been taken at the February 15 evaluation. While growth was notably slower in the control beds, the lettuce mix was apparently

not hurt by the below zero temperatures, and seemed well suited to winter production in the high tunnel.

Winter Density: *Winter Density* did not live up to its name in this trial. At the first evaluation on January 14, the *Winter Density* bibb lettuce heads in all the treatment beds looked good (Photo 1), and plants in the beds with low row covers had markedly increased growth relative to the controls (Table 6). The cold snap in late January, however, destroyed all the winter density heads in all the treatment beds (Table 7). Below zero temperatures proved to be a real problem for this variety, and the low row covers did not appear to help. If *Winter Density* is going to be used for high tunnel production, it should probably be harvested early in the winter, before the potential arrival of very cold temperatures.

Butterhead lettuce: Butterhead varieties are known to produce some of the finest spring lettuce. This trial tested one green butterhead, *Nancy*, and one red butterhead, *Skyphos*, to see how they would perform during the winter in a high tunnel. Both varieties surprised us with excellent growth under the low row covers (Tables 6&7), and decent cold tolerance in all the treatment beds. The plants had not managed to form a mature head by the second evaluation on February 15, but the heads under the low row covers appeared to be getting close. Higher planting densities on the growing beds would likely help optimize production of these high quality leaves. The butterheads were planted 12" apart in this trial; an 8" plant spacing might be preferable.

Spinach: *Tyee* spinach exhibited more growth under the low row covers than in the control beds, but all the spinach beds looked good, and were unfazed by the below zero temperatures.

Salad Turnips: *Hakuri* salad turnips have become a popular direct market crop in this area. The turnips in this study transplanted well and grew well in the early winter high tunnel environment. The plants really benefited from the low row covers in terms of increased growth by the January 14 evaluation (Table 6). Uncovered salad turnips were all killed by the late January cold snap, while the salad turnips under the low row covers were still firm and fresh. Depending on the market, salad turnips could be an option for winter production as long as low row covers are provided.

Claytonia: As with many of the other entries, the *Claytonia* plants grown under low row covers performed very well in this trial. At the January 14 evaluation, the covered *Claytonia* exhibited much more growth than the uncovered control plants (Table 6). Uncovered plants were also hit hard by the below zero temperatures, while the plants with row covers remained undamaged and continued to grow (Photo 2). The size of the covered plants in this trial was encouraging, and *Claytonia* could be a nice option for winter production depending on market demand.

Mache (corn salad): *Vit* corn salad is known to be very cold tolerant, and the plants in this trial were not visibly damaged by very cold temperatures. The plants, however, were not particularly productive. They were small at transplanting time and did not really grow much until after the January 14 evaluation. Growth was higher under the low row covers by the February 15 evaluation, but the plants were small relative to the other greens in the trial.

Carrots: The *Nelson* carrots were a favorite of the field mice that created some problems with this study. Almost all the carrots were destroyed shortly after transplanting.

Conclusion: This trial showed that low row covers can greatly enhance the quality and productivity of late-planted greens grown for winter harvests in a high tunnel. With several of the greens in this study, plants were able to thrive under the low row covers while uncovered counterparts were killed or greatly damaged by below zero temperatures.

All the crops, including the carrots and salad turnips, transplanted well, but the feasibility of transplanting the very high density root crops, or salad mixes remains a question. Surprising crop options that warrant a second look include the butterhead lettuces, *Claytonia*, and *Hakuri* salad turnips.

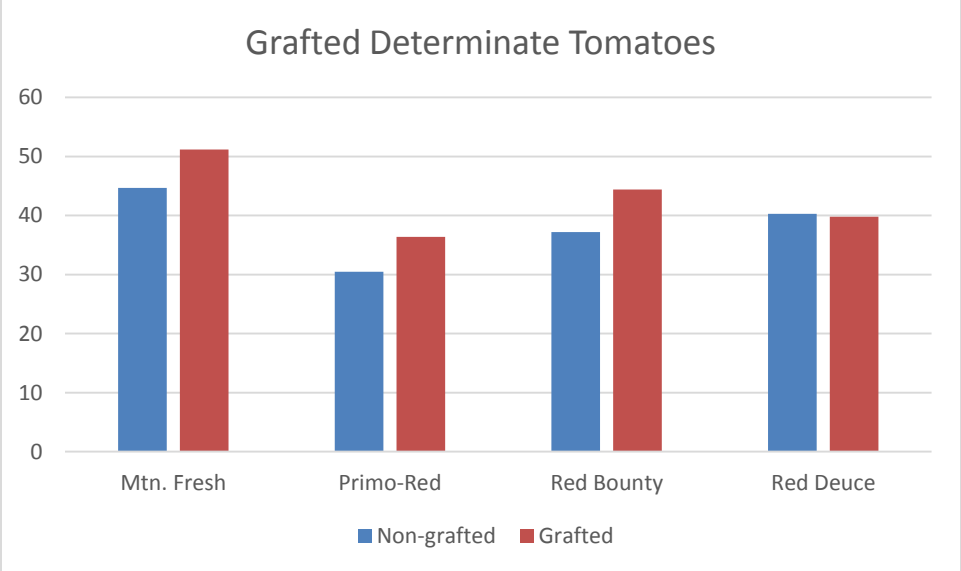
Tomato Trial Cornell Willsboro Farm 2013

Seeds of four commercial determinate tomato varieties, *Red Bounty*, *Red Deuce*, *Mountain Fresh*, *and Primo-Red*, were started in a germination chamber in early spring. Seeds of *Maxifort*, a vigorous, disease resistant tomato rootstock, were started at the same time. All seedlings were transplanted into 36 cell trays two weeks after seeding. Four weeks after seeding, half of the seedlings for each of the four commercial varieties were side-grafted onto *Maxifort* rootstock seedlings. Grafting success rate was over 90% for all four commercial varieties.

A variety trial evaluating the performance of the four commercial tomato varieties, both with and without grafting to the *Maxifort* rootstock, was established in a high tunnel on the Cornell Willsboro Research Farm. A randomized completer block experimental design with four replications was utilized. Tomato plants were trellised using a stake and weave system, and drip tapes were installed for irrigation and fertigation. Yield data was collected weekly and through the fall in the tunnel environment.

Results and Discussion

The grafting procedure set the plants back such that the grafted tomatoes started producing ripe fruit 7-10 days later than the non-grafted plants. *Mountain Fresh* produced the highest mean total fruit yield of the four determinate varieties, while *Primo Red* had the lowest mean yield (Figure 1). With three of the four varieties the grafted plants produced more total fruit yield than non-grafted plants. *Red Deuce* was the exception as fruit yields for grafted and non-grafted *Red Deuce* plants were similar.



Total 2013 Fruit Yields (mean pound per plot) for grafted and non-grafted determinate tomato varieties.

Cucumber Grafting Technique Willsboro 2013

Cucumbers are another popular and profitable high tunnel crop. Cucumbers are sensitive to cold temperatures, however, and it can be a challenge to establish cucumbers in unheated high tunnels early in the spring. One strategy for improving early season establishment involves grafting greenhouse cucumber scions onto vigorous, cold tolerant squash seedlings. This project evaluated a number of techniques and strategies for grafting *Cucapa* cucumbers onto four different squash rootstocks, *Tetsukabuto*, *Titan*, *Shinitosa*, and *Marvel*.

First Attempt: A single cotlyledon grafting approach was used in the first attempt. This technique utilized young seedlings that had just started to produce their first true leaf (grafting occurred 10 days after seeding). A 45 degree cut on the squash rootstock ideally retained one cotyledon while removing the axillary buds along with the other cotyledon. A 45 degree cut through the stem of the *Cucapa* scion was made and the scion was grafted to the rootstock with a spring loaded grafting clip. Grafted seedlings were misted and placed in a dark healing chamber for three days before gradually exposing the plants to light. None of the grafted seedlings survived.

Second Attempt: In the second attempt older seedlings were used for grafting, and since the cucumbers scions had been found to be slower growing than the squash rootstock, the cucumber scions were seeded a week before the squash rootstock. During grafting, the stems of the squash rootstock seedlings were cut below the cotyledons at either a 45 degree angle or with a v-notch. *Cucapa* scion stems were then cut to match the cut on the squash rootstock and the scion was joined to the rootstock with a spring loaded clip. Grafted seedlings were misted and placed in a dark healing chamber for three days. Success rates with the different cuts and rootstock are shown below. Second attempt results suggest that the *Shintosa* rootstock may be better suited for cucumber grafting than the other rootstocks tested, and the 45 degree cut worked much better than the v-notch cut.

2013 Cucumber Grafting Results

Rootstock	Stem cut	Percent survival
Tetsukabuto	45 degrees	0
Tetsukabuto	V-notch	0
Shintosa	45 degrees	50
Shintosa	V-notch	17
Marvel	45 degrees	17
Marvel	V-notch	0
Titan	45 degrees	0

All scions are *Cucapa*

Tolerance of select high tunnel determinate tomato varieties to leaf mold, 2013. Penn Yan

Transplants of four determinate tomato cultivars for high tunnel production were raised in a heated greenhouse on a grower cooperator's farm in Penn Yan, NY. Plants were sown on 5 Feb 13 into an open tray and were transplanted 2 weeks later into 1204 cells. The farm-fabricated 30 ft. by 120 ft. galvanized steel high tunnel was covered with 6 mil Tuff Lite IV polyethylene film. On 9 Apr, transplants were placed in the high tunnel soil (Lima silt loam) in a single row spaced 16-in. apart on slightly raised, black plastic mulched beds with drip tape. Four replications with five plants/plot were established following a randomized complete block design. Supplemental forced air heat with a thermostat set point of 45 °F was provided as needed to protect transplants during cold weather events through April. Cultural management and fertigation were maintained to the grower's standards. No fungicides were applied. Leaf mold (*Passalora fulva*) severity was rated on a percent dieback scale (0-100), where 0 represented no visible infection symptoms and 100 represented plant death. Ratings were taken on 17 Jul, 12 Aug, 3 Sep and 16 Sep. Data analysis was conducted using statistical software and analysis of variance (ANOVA) procedure, with significance groupings determined using Fisher's protected least significant difference test.

Leaf mold caused substantial defoliation on 'Volante' and 'Red Bounty', with the disease progressing at a similar rate in these varieties. Conversely, neither 'Primo Red' nor 'Red Deuce' exhibited symptoms of leaf mold throughout the trial. While 'Primo Red' is known to carry resistance to *P. fulva*, the apparent resistance exhibited by 'Red Deuce' in this trial is new information. 'Red Deuce' yielded significantly higher than the other varieties.

Variety	Final Mean Brown Leaf Mold Rating (%)	Marketable yield (lb./plant)
Primo Red……....	0 a*	20.5 b
Red Deuce……....	0 a	23.8 a
Red Bounty……....	86.1 b	20.3 b
Volante……..	80.6 b	19.9 b
P value	<0.0001	0.0288

* Means with the same letters are not significantly different according to Fisher's protected LSD test ($P = 0.05$).

Grafting of Tomatoes for Soil-based Production in Greenhouse and High Tunnels
Judson Reid, Kathryn Klotzbach and Nelson Hoover

Introduction

Soil based greenhouse and high tunnel production of tomatoes has risen dramatically in the Northeast in the last decade. A recent USDA report indicates that the adoption of hoop house technology has allowed states such as New York to become leaders in season extension[1]. This season extension technology offers farmers an opportunity to target market price peaks and capitalize on the rising demand for locally grown produce. Tomatoes from these protected culture systems have proven profitable in wholesale auction settings as well as farmer's markets and CSA's.

However, as production continues in the same soil, risk of root-zone diseases, nematodes and soil nutrient deficiencies increase. Grafting, the combination of two separate cultivars into one plant, is one management approach to these challenges.

Materials and Methods

On February 21, 2012 seeds of tomato scion varieties Big Dena and Panzer; and rootstock varieties Maxifort and Arnold were sown in a soilless potting mix (Promix, Premier Horticulture) at a cooperating greenhouse in Penn Yan, NY. Seeds of rootstock variety Colossus were sown on February 22. All varieties were transplanted to 50-cell flats at first true leaf stage, on March 6. On March 23 grafts were made with the three root stock varieties and two scions, for a total of 6 combinations, 40 finished plants per combination. Cuts were made with a double-edged razor blade on a 45°-angle across the stem of both varieties, immediately above the cotyledons, the union was then joined with 2 mm silicon grafting clips. Grafted plants in 50-cell trays were placed immediately in a darkened healing-chamber with 100% relative humidity and temperature of 80-84 °F. Grafted plants were gradually re-acclimated to greenhouse bench conditions, with increasing intervals of time out of the healing chamber, until complete acclimation, approximately 12 days post-grafting. Grafted plants were transplanted into an unheated high tunnel with a Lima Silt Loam soil on April 18. Fertilization was carried out per grower standards, detailed in the attached appendix. Plants were grown on a vertical trellised and pruned to a single growing point.

Graft survival was recorded with viable plants available on April 18. Number of fruit per block and total weight per block was recorded at each harvest, beginning June 6 and ending October 30. Data were analyzed using statistical software Analysis of Variance (ANOVA) procedure, and treatment means were separated using Fisher's Least Significant Difference ($p \leq 0.05$).

Results

[1] Winter Farmers Markets Expand, Now More than 1,200 Locations for Fresh Local Foods. (2011). www.usda.gov

Survival of grafted plants was highest with Colossus rootstock, with an average of 94%, followed by Maxifort with 84% and Arnold 73% (Chart1). When examining graft survival based on scion, Big Dena had an average 86% survival across the two rootstocks and Panzer 79%.

Grafting significantly increased yield of both scion cultivars (Table 1). The highest yielding combination as measured by pounds per plant was Big Dena X Maxifort with a value of 30.6. Panzer X Maxifort followed with 29.16 lbs per plant.

Discussion

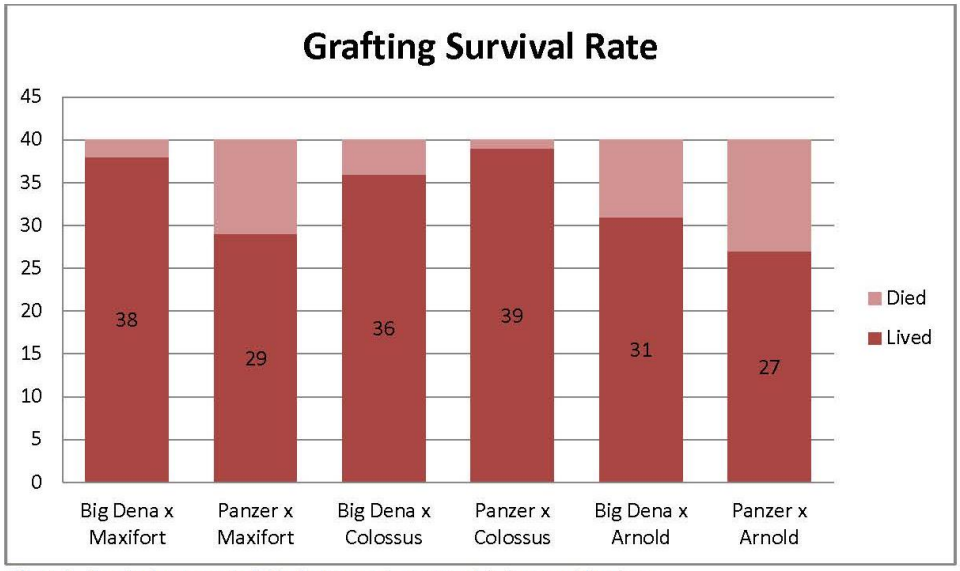


Chart 1. Survival rates out of 40 plants per six rootstock/scion combinations.

Table 1. Yield measures of two tomato varieties ungrafted, and grafted to three different rootstocks.

	Mean Fruit Weight (lbs)	Total Fruit per Plant	Mean Plant Yield (lbs)
Big Dena	0.64 bc	38.31 c	24.54 cd
Big Dena x Maxifort	0.70 a	43.69 ab	30.60 a
Big Dena x Colossus	0.68 ab	39.69 bc	26.80 bcd
Big Dena x Arnold	0.72 a	37.56 c	26.85 bc
Panzer	0.55 e	44.58 a	24.42 d
Panzer x Maxifort	0.62 cd	47.19 a	29.16 ab
Panzer x Colossus	0.60 cde	47.00 a	28.11 b
Panzer x Arnold	0.58 de	47.88 a	27.61 b
p-Value	***0.0000***	***0.0001***	***0.0003***

*Means with different letters (grouping) differ significantly according to Fishers's Protected LSD ($P<0.05$).

Discussion

Graft survival rate is not likely related to cultivar compatibility. Two of the authors conducted the grafting process and differences in technique may account for variability in survival. It is critical however, to match the scion stem diameter as best as possible to root stock stem diameter. Vigorous scions such as Panzer could be started several days after all of the root stock used here.

Grafting of Panzer scions onto all rootstock trialed here offered significantly higher production than the ungrafted controls. Big Dena yield was higher on all rootstock, but only significantly separate from ungrafted when grafted to Maxifort. It should be noted this trial took place in 'fresh' tunnel soil that had not seen vegetable production for several years. In other work by the Cornell Vegetable Program it has been noted that yield response to grafting is greater at sites that have a recent history of intensive tomato production.

Yield as measured by pounds per plant, is perhaps the most important metric in this trial, however it is not the only one needed for selecting a scion/rootstock combination. The grower noted a preference for Panzer fruit, based on color and shape. The three rootstock X Big Dena combinations gave the significantly heaviest fruit weight, creating their own grouping. Fruit size may be an important attribute for some markets.

Yield precocity is also important for tomato marketing, as a price differential exists for early season fruit.

Conclusions

Economics of grafting is favorable based on the yield increase in this trial. The estimated cost of a Maxifort X Panzer is 1.50/plant vs. ungrafted panzer at 0.36/plant. With a mean increase of 4.7 lbs per plant, the break-even price required is 0.24 per lb. It should also be noted that this trial site had not been cropped in several years. As many tunnels have soil further compromised than this site, yield differences between grafted and non-grafted will likely be higher.

Figure 1. Successful grafts of Big Dena onto Maxifort.


Figure 2. Grafted tomato trial in an unheated high tunnel.

Cucumber Trellising Trial – Willsboro Farm – Summer 2014

Method

We compared two training methods of one variety of cucumber, *Cucapa*, which is well suited to high tunnel production. This variety is parthenocarpic, meaning it is self-fertile and does not need bees for pollination. This is an important characteristic to address in tunnel production where bees do not visit as often as field grown crops. It is important to train cucumbers vertically in tunnels to minimize the ground space they occupy while maximizing yield. Vertical training also increases air circulation which helps reduce disease pressure such as powdery mildew. We tracked yield and hours of labor to train and harvest each method. Seedlings were transplanted on May 28, 2014 and final harvest was on October 16, 2014.

Results

Growers are reluctant to try training cucumbers to a single leader, assuming that more labor will be involved for a similar yield. At the grower field meeting in late July the mesh trellised plants were bushier and looked as though they would yield more than the more spindly, single leader plants. But our data showed otherwise. Training cucumbers to a single leader resulted in a 20% greater yield and used 1.2 hours less labor over the season than cucumbers trained up a mesh trellis, which is an insignificant difference. Cucumbers are sold by the piece and the trellised plants yielded a total of 1014 fruits while those trained to a single leader yielded a total of 1275 fruits. Labor included both training and harvesting the crop.

	Trellised	**Single Leader**
Yield	1014 fruits	1275 fruits
Labor	15.23 hrs.	14.48 hrs.

Conclusion

Cucumbers thrive when allowed to grow up a trellis and yield per square foot is optimized. Parthenocarpic and disease resistant varieties are ideal for tunnel production. Although our plantings continued to yield well into October, most growers find their first plantings cease production by mid-August. Growers might consider two plantings, one in late May and a second in late June for an extending cropping season.

Training plants to a single leader did not take more time than the mesh trellis and with the increased yield and air circulation growers are advised to consider this option.

Left: Two of the 3 replications comparing methods of training cucumbers: single leader on far left and right, mesh trellis in center 2 rows.

Winter Greens Trial – Cornell Willsboro Research Farm – Sept. 2014-June 2015

Objectives

- To determine whether fall-seeded Salanova lettuce varieties could be overwintered in an unheated high tunnel.

- To evaluate the productivity of Salanova lettuce varieties seeded in late winter and early spring, and grown in an unheated high tunnel.

Fall Seeded Lettuce

Methods

Eight Salanova varieties were seeded on three planting dates spaced about two weeks apart in the fall of 2014. Seeds were planted into 72 cell trays with Vermont Compost Fort V growing mix, and germinated on heat mats in a germination chamber equipped with fluorescent grow lights. Germinated seedlings were moved to the high tunnel and grown in the trays for four to six weeks prior to transplanting into the growing beds. All growing beds were covered with two layers of Agribon-19 row cover stretched over wire hoops. Beds were left covered through the winter, and the condition of the lettuce plants was evaluated on March 31, 2015. A randomized complete block experimental design with three replications was employed.

Results and Discussion

The 2014-2015 winter was very cold. There were several periods with below zero nighttime temperatures, and daytime temperatures rarely rose above the freezing mark during January and February.

Seeding date had a huge impact on lettuce winter survival (Table 1). None of the lettuce plants in the third seeding on 10/18 survived the winter, and very few lettuce plants from the second seeding on 10/2 survived. In contrast, many of the Salanova lettuce varieties from the first seeding on 9/16 had very high winter survival rates. *Green Oakleaf*, *Red Oakleaf*, and *Red Butter* all had winter survival rates of over 90% in the first seeding. The one exception was *Green Sweet Crisp*, which didn't have any plants from the first seeding date survive the winter. *Green Sweet Crisp* is one of the highest producing Salanova varieties in terms of leaf production per plant, so it was unfortunate that this variety had such poor winter survivability.

Conclusion

These results illustrate that winter survival differed with Salanova variety and planting date. They further suggest that very young plants that have not had a chance to get well established in the growing beds are less able to withstand cold winter temperatures. It should be noted that with the lettuce plants that did survive the winter, any leaf tissue that had been produced in the fall was brown and deteriorating by the time the plants were evaluated in March. All the harvestable leaves on the surviving lettuce plants were produced after the temperatures and growing conditions improved in late winter and early spring.

Table 1.			
Mean Winter Survival			
Evaluated 3/31/2015	Seeding 1	Seeding 2	Seeding 3
Seeding Date:	9/16/2014	10/2/2014	10/18/2014
Transplant Date:	10/16/2014	11/3/2014	12/1/2014
Salanova Type	*% Survival*	*% Survival*	*% Survival*
Green Lollo	83.3	0	0

Red Lollo	75	8.3	0
Green Sweet Crisp	0	8.3	0
Red Sweet Crisp	66.7	0	0
Green Butter	41.7	0	0
Red Butter	91.7	16.7	0
Green Oakleaf	100	8.3	0
Red Oakleaf	91.7	0	0

Late Winter-Early Spring Seeded Lettuce

Methods

Eight Salanova lettuce varieties and one butterhead lettuce variety (*Skyphos*) were started in 72 cell trays on three planting dates in late winter/early spring 2015. Seeds were germinated on heat mats indoors, and then trays of germinated seedlings were moved to the high tunnel where they were grown under Agribon-19 row covers for four to five weeks prior to being transplanted into the growing beds. A randomized complete block experimental design with three replications was used. The productivity of all three seedings was evaluated on 6/11/2015.

Results and Discussion

All the late winter-early spring seedings produced excellent quality lettuce. Since seedings four, five, and six were all harvested at the same time, lettuce yields decreased with later seeding dates because the lettuce plants were in the growing beds for a shorter period of time (Table 2). Lettuce yields per plant differed markedly with Salanova type. *Green Sweet Crisp* consistently produced much higher yields than any of the other Salanova types, and it also consistently out yielded the *Skyphos* butterhead type. As a group, the four leafy Salanova types (*Green Sweet Crisp*, *Red Sweet Crisp*, *Green Lollo*, and *Red Lollo*) were higher yielding than the four "cored "types (*Green Butter*, *Red Butter*, *Green Oakleaf*, and *Red Oakleaf*)(Figure 1). With the cored types the leaves need to be cut away from the central stem to produce a salad mix. In this study, weights of the entire shoot (leaves and stems) were recorded, so the lettuce leaf yield difference between leafy and cored Salanova types would be expected to be even greater than what we observed.

Conclusion

Late winter-early spring seedings of Salanova lettuce plants that are transplanted into an unheated high tunnel can produce high quality lettuce as either small heads or a lettuce mix. The leafy Salanova types tend to be higher yielding than the cored types, and, given that they are all planted at the same density on the growing beds, return per square foot of growing space could potentially be higher with the leafy types. It was interesting that the leafy Salanova per-plant yields were comparable to the butterhead lettuce (*Skyphos*), even though the butterhead plants were grown at a lower plant density. Butterhead lettuce tends to command a relatively high price, so a careful market analysis would be required to determine which option would be more profitable on a square foot growing space basis.

Table 2.			
Yield/Plant (grams)			
Harvested 6/11/15	Seeding 4	Seeding 5	Seeding 6
Seeding Date:	2/16/2015	3/12/2015	3/31/2015
Transplant Date:	4/1/2015	4/22/2015	5/12/2015
Salanova Type	*grams/plant*	*grams/plant*	*grams/plant*
Green Lollo	335.4	253.3	176.1
Red Lollo	270.7	290.3	126
Green Sweet Crisp	774.9	672.8	261.5
Red Sweet Crisp	264.5	334.8	205.9
Green Butter	164.7	158.5	168.3
Red Butter	266.7	229.1	157.7
Green Oakleaf	126.1	118.6	197.4
Red Oak leaf	197.4	221.4	163.8
Skyphos (Butterhead)	359.7	267.3	230.2

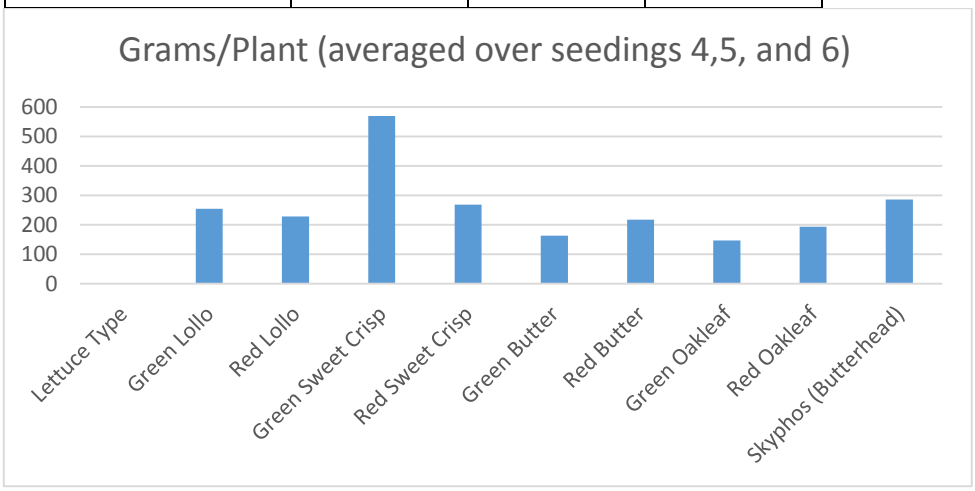


Figure 1. Mean per-plant lettuce shoot yields averaged over three seeding dates.

Cornell University
Cooperative Extension

BEST MANAGEMENT PRACTICES
IN HIGH TUNNEL PRODUCTION

Site Selection

You've decided to add a high tunnel to your farm. Deciding where to put the structure comes next, and it is a step that requires careful consideration. After all, behind the type of structure you choose, location is the hardest thing to change about your high tunnel production system. A good site will set you up for success by avoiding potential problems. A poor site may work for a season or two, but inconvenient access, excessive water, poor soil, high winds, or low light levels will eventually decrease profitability or lead to property loss.

Convenience

High tunnels can be an asset, but only if they are well managed. Good management requires frequent monitoring, particularly during the colder months.
It is most beneficial to choose a site that provides the following conveniences:

- Proximity to a farm house or main building
- Year round access to entire structure
- Good water and electricity nearby
- Close to cooling/packing facilities

Remember-out of sight is too often out of mind.

This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture through a grant from the New York State Department of Agriculture and Markets. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA or NYS DAM.

Topography and Surface Water

Infiltrating water may begin as a nuisance in a high tunnel, but easily becomes a yield limitation. Water flowing over land or pooling from tunnel run-off can cause muddy conditions, favor disease, drown plants, and cause erosion. It also leads to uneven soil moisture, which frustrates irrigation efforts and can cause fruit to crack.

To avoid saturation problems, look for a level site on high ground. A very slight pitch down the length of the tunnel is desirable. The soil level in the tunnel should be slightly higher than the surrounding field. If such a site is not available, keep the tunnel out of the path of surface water flow by:

- Intercepting and diverting water away from tunnel with shallow ditches or furrows along the outside perimeter
- Improving drainage in surrounding areas with tile drainage where feasible
- Ensuring adequate water removal or percolation along the inside sidewalls

Soils

High tunnel production is intensive and demanding of soils. Tunnel soil does not benefit from leaching like a field, may become compacted, and is at higher risk for loss of both structure and organic matter.

Good high tunnel soil:

- Has good physical structure, drainage, pH, and organic matter
- Is not compacted
- Is free of soil-borne diseases

Maintaining soil health requires adding organic matter, avoiding over-fertilization and rotating crops. The details of sustaining tunnel soil health are the subject of another Best Management Practice bulletin.

Light, Wind, and Orientation

Choose a site that receives full sun and is free from shadows for the entire length of your growing season. For best winter production, orient the tunnel east to west to maximize light capture and distribution throughout the low sun-angle months. Summer row crops may benefit from a north to south orientation, although orientation this time of year is not as critical as winter.

The site should be protected from strong winds while allowing sufficient airflow through the house during the growing season. A sheltered site, combined with structural design and management will prevent the house from taking flight during windstorms. If possible, orient tunnels perpendicular to the prevalent wind direction to protect the weak endwall from exposure.

- Study wind patterns at potential sites. Consider direction and strength in severe weather for all seasons, with particular attention to April-October
- Do not site the tunnel in a wind tunnel!
- Make use of natural windbreaks, while avoiding their shadows
- Orient the tunnel to accommodate both wind direction and light needs

In windy location use plenty of ground anchors and diagonal bracing, and fortify the end walls.

Tax, Building code, and Zoning Considerations

Growers are encouraged to contact local code or zoning enforcement officers to discuss local ordinances. In New York, high tunnels are generally considered agricultural equipment and not real property, thus they are exempted from property tax and New York State building codes.

Growers may apply for a permanent real property tax exemption provided no washing, packaging, or other post-harvest processing of produce occurs within the tunnel. The one-time application form, NY State tax form RP-483c, is available online at http://www.tax.ny.gov/pubs_and_bulls/orpts/farmbld.htm

Although building permits are not required, growers may have to obtain a zoning permit. Other important legal documents concerning high tunnels can be found here:

- http://www.agriculture.ny.gov/AP/agservices/GD_FP%20and%20Ag%20Districts_%20FINALJPC.pdf
- http://www.dos.ny.gov/DCEA/pdf/TBtempgreenhouse07.pdf
  Finally, note that regulations and local interpretation of enforcement change over time and geography.

Websites:

Cornell High Tunnels:
http://www.hort.cornell.edu/hightunnel

High Tunnels Manual – by Ted Blomgren, Tracy Frisch: http://www.uvm.edu/sustainableagriculture/hightunnels.html

Team High Tunnel Website:
http://cvp.cce.cornell.edu/greenhouse_tunnels.php

Prepared by:
Elizabeth Buck, Cornell Vegetable Program
May 2014

Cornell University
Cooperative Extension

BEST MANAGEMENT PRACTICES
IN HIGH TUNNEL PRODUCTION

Optimal Spacing
for High Tunnel Tomatoes

Proper spacing is a common concern of high tunnel growers. In an effort to achieve the greatest production, plants are often set too closely together. More plants does not necessarily mean more yield.

Crowded plants compete with each other for water and nutrients; their dense foliage reduces air circulation creating ideal conditions for foliar diseases; and maneuvering through the crop for harvesting and training is more difficult. Fewer plants, grown better, will out-yield more plants, grown under crowded conditions.

Spacing includes both the distance between plants in the row as well as distance between the rows. Determinate varieties are spaced and trained differently than indeterminates, and grafted plants need more room than non-grafted. See reverse side for a summary and diagram of suggested layouts for each type of tomato.

A well-spaced planting allows room for the grower to move down the aisles for harvesting, training and scouting for pest and disease problems.

Photo on left: *June 14. This tunnel shows good spacing; the plants will become even more dense as the season progresses. These plants also need diligent training to focus plant energy on fruit production rather than excess leaf production.*

Photo on right: *July 13. Same tunnel. Optimum use of space.*

Photo on right: *Aug 10. In this tunnel, the rows were set only 2 feet apart so the plants quickly filled all available space making harvesting and managing the crop a real challenge, and there is still over a month of growth and harvest to come.*

Optimal Spacing for High Tunnel Tomatoes

Between row spacing:

For all types of tomatoes the between row spacing ('center-to-center', or bed spacing); is a minimum of 4 feet, preferably 5 feet (see diagram B).

This is a bit site specific as tunnels come in different widths.

- For a 20' wide tunnel you can squeeze in 5 rows (4' spacing)
- For a 30' wide tunnel you can fit in 6 rows (5' spacing)

Avoid crowding your plants – you'll get more yield with fewer plants well trained. Disease pressure is reduced, harvesting is efficient, air circulation is increased.

In-row spacing:

For determinate types: (*see Diagram A*)

- Train using the basket weave method
- Set plants 18" apart in a single row
- Set a stake between every 2 plants

For indeterminate types: (*see Diagram B*)

- Train plants to a single leader
- Set plants in a double staggered row
- Set plants 24" apart in row

For grafted plants: - train to double leaders (result is a V-shaped plant)

- Option A – a double staggered row
  - 24" from each leader which means 48" between the central root stock.
  - This comes down to the same stalk density as the 24" double row of indeterminates, above.
- Option B – a single row
  - Set plants 24" apart in a single row

This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture through a grant from the New York State Department of Agriculture and Markets. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA or NYS DAM.

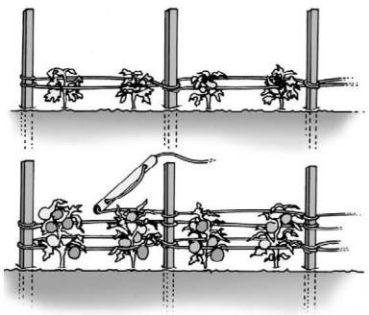


Diagram A: the basket weave method of training determinate tomatoes

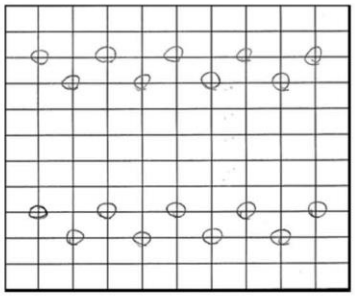


Diagram B: the proper bed spacing for all types of tomatoes and the in-row spacing for a double staggered row of indeterminates
Scale: 1 square = 1 foot

Prepared by Amy Ivy, ENY Horticulture Program and Judson Reid, Cornell Vegetable Program - April 2013

Marketing Considerations: *Fruit*

The physical and sensory qualities of the tomato fruit may be the most important factor in varietal selection. Growers who seek firm fruit suitable for wholesale packing and shipping can find satisfactory varieties in both categories. Heirloom tomatoes, renowned for their taste and unique colors, are nearly all indeterminate. Satisfying the demands of the market is critical to success. Once the desired fruit attributes have been determined, a suitable variety can then be selected in either the indeterminate or the determinate category.

Varieties to Consider for the High Tunnel		Determinate	Indeterminate
Primo Red	*disease resistant hybrid for packing or direct sales*	✓	
Red Mountain	*disease resistant hybrid for packing or direct sales*	✓	
Red Deuce	*disease resistant hybrid for packing or direct sales*	✓	
Geronimo	*disease resistant hybrid for packing or direct sales*		✓
Rebelski	*disease resistant hybrid for packing or direct sales*		✓
Panzer	*disease resistant hybrid for packing or direct sales*		✓
Rose de Berne	*pink, medium sized heirloom*		✓
Nyagous	*'black', medium sized heirloom*		✓
Arkansas Traveler	*red, medium sized heirloom*		✓
Pike County Yellow	*yellow, large sized heirloom*		✓

Useful Websites:

Cornell High Tunnels: http://www.hort.cornell.edu/hightunnel

Team High Tunnel Websites: http://cvp.cce.cornell.edu/greenhouse_tunnels.php And http://enych.cce.cornell.edu/greenhouse_tunnels.php

Prepared November 2014 by Cordelia Hall

Judson Reid and Amy Ivy, Project Coordinators

Photo credits: Amy Ivy and Judson Reid

This publication was supported by the Specialty Crop Block Grant Program at the U.S. Department of Agriculture through a grant from the New York State Department of Agriculture and Markets. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA or NYSDAM.

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BEST MANAGEMENT PRACTICES IN HIGH TUNNEL PRODUCTION

Tomatoes for High Tunnels

Determinate versus Indeterminate

One of the first choices when beginning high tunnel tomato production is variety. Tomato varieties fall into one of two categories: determinate or indeterminate. Both types of tomatoes can be grown successfully in a high tunnel. Differences in the growth habits, nutritional needs, disease resistance, and fruit attributes of determinate and indeterminate tomatoes will influence the varieties a grower will choose. The following comparison guide will help

In this photo, determinate plants are on the left with the wooden stakes, indeterminate plants are on the left, individually trained up a length of twine.

***Determinates** are shorter, with more restricted branching and a concentrated harvest period.*

***Indeterminates** are tall and vining with an extended harvest period.*

Management Considerations: *Trellising*

Determinate Varieties

- 4-6' wooden stakes are placed in-row with twine strung horizontally on either side of the row to guide plant growth upward.
- This method may require 6-8 applications of twine to trellis plants adequately.
- Trellising labor ends mid-season due to the determinate growth pattern.

Indeterminate Varieties

- Can also be trellised with stakes and twine, but are often grown 'greenhouse style' in high tunnels.
- Plants are pruned to one or two leaders (see pruning section) and attached to vertically suspended twine with plastic clips.
- Small spools allow lowering of the twine as plants grow.
- Indeterminate plants will continue to grow upward and require trellising throughout the season.

Management Considerations:

Pruning Techniques

Determinate Varieties

- Require dramatically less pruning than indeterminate tomatoes.
- Approaches vary, but the Cornell Vegetable Program recommends pruning all but the last secondary shoot (suckers) below the first flower, forming a "Y" structure.
- This requires a one-time removal of approximately five suckers.

Indeterminate Varieties

All suckers are pruned to create a single dominant growing point, which in turn facilitates vertical trellising.

- Some growers allow two growing points, which are treated as separate plants and pruned of all suckers.
- Pruning is a season long task.

Strong Y pruning of a determinate plant.

Harvest & Yield

Yield varies by variety, but there are high yielding varieties in both categories. While we have achieved yields of 30 lbs. per plant with both types in our trials, the timing of harvest is dramatically different. Determinate plants have a more concentrated early harvest of fruit, while indeterminate varieties will yield more evenly over the harvest season. Indeterminate varieties are likely to provide more high quality fruit in the late season than determinate varieties.

Left: Determinate trellis and fruit load

Above: Indeterminate vines can be lowered as the season progresses

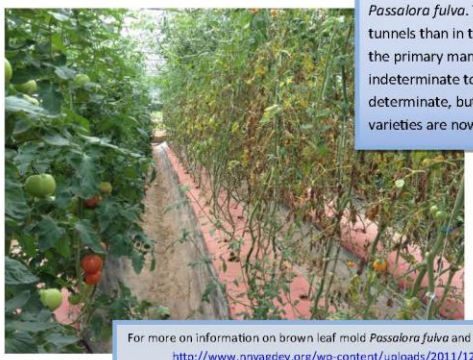
Fertility

As total yields can be similar between determinate and indeterminate varieties, their fertility needs are quite similar. However, with concentrated fruit maturation on determinate varieties deficiencies in potassium, magnesium and phosphorus may develop more quickly than in indeterminate varieties. Indeterminate varieties, on the other hand, may require more evenly spaced nitrogen applications as their vegetative growth will continue throughout the season. Based on fertility needs, growers should consider their ability to deliver soluble nutrients such as nitrogen and potassium in both scenarios.

Labor

Indeterminate varieties require ongoing pruning, clipping and harvesting, while determinate varieties are trellised and harvested over shorter periods. However, the upright open canopy of indeterminate varieties facilitates easier harvest. Harvest of determinate varieties requires kneeling and searching for ripe fruit within the dense canopy.

The foliar disease of primary concern in high tunnels is Brown Leaf Mold, caused by the fungus *Passalora fulva*. This disease is more severe in tunnels than in the field and varietal resistance is the primary management tool. There are more indeterminate tomatoes with resistance than determinate, but several resistant determinate varieties are now on the market.



In this picture, Rebelski is on the left and is leaf mold resistant. On the right is SunGold, a susceptible variety.

For more on information on brown leaf mold *Passalora fulva* and a list of resistant varieties by Amy Ivy visit: http://www.nnyagdev.org/wp-content/uploads/2011/12/Leaf-Mold-on-Tomatoes-final.pdf

Additional Tips

Suckering

- When pinching out suckers, the earlier they are removed, the better. Once the suckers are thicker than a pencil they will leave a large wound behind when removed.
- Smaller suckers are easy to pinch off with fingers, using a sideways motion; larger suckers are best removed gently with a sharp knife, using care to not damage neighboring tissue.

Suckering Indeterminates

- It takes regular maintenance to keep ahead of the suckers, especially during the first 6 weeks of growth.
- Check at least twice a week during this period to catch the suckers when small. Spending a little time on a regular basis will have much better results than a larger effort, done less often.

Line and Clips for Trellising

- Various types of line are available. Nylon is the most durable, natural fibers deteriorate as the weight of the crop increases. Baling twine is not suitable.
- Tomato clips come in 2 weights as well as compostable. Reviews are mixed of the compostable type in regard to durability.

Well managed tomatoes:
Determinates on left, indeterminates on right.

Cherry-type Tomatoes

Cherry tomatoes produce rampant growth that is difficult to keep under control. Some growers start with a double leader system, others let them develop multiple leaders although rigorous suckering is not practical on a large scale. Fortunately, vigor and production are usually high enough that a good yield is still achieved.

Useful Websites:

Cornell High Tunnels: http://www.hort.cornell.edu/hightunnel
High Tunnels Manual – by Ted Blomgren, Tracy Frisch: http://www.uvm.edu/sustainableagriculture/hightunnels.html
Team High Tunnel Websites: http://cvp.cce.cornell.edu/greenhouse_tunnels.php
And http://enych.cce.cornell.edu/greenhouse_tunnels.php

Text and photos by Amy Ivy, Eastern NY Commercial Horticulture Program, Nov 2014. adi2@cornell.edu

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BEST MANAGEMENT PRACTICES
IN HIGH TUNNEL PRODUCTION

Training & Pruning Tomatoes

Tomatoes thrive in the protected conditions of a high tunnel. Well trained and well pruned tomatoes are easy to work around, have better air circulation, optimum light penetration, and have higher yields since excess foliage is removed to focus plant energy on producing and ripening fruit. If left untrained, tomatoes will quickly form a tangled mess that is difficult to maneuver through and harvest, and problems can go unnoticed until they are too late to stop.

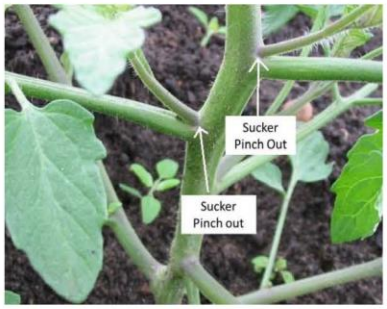
A well-managed planting allows room for the grower to move down the aisles for harvesting, training, and scouting to catch any pest and disease problems early. See another publication in this series, '*Optimal Spacing for High Tunnel Tomatoes*' for specifics on spacing between the plants and diagrams for laying out the rows in tunnels. The websites listed on page 4 include these and other resources.

There are two key types of tomatoes based on their growth habit called determinate and indeterminate, and they are managed differently.

- **Determinate** tomatoes grow to about 4 feet high and produce most of their fruit in a few weeks, although they will continue to bear some until frost. They have a bushy habit and do best with support along their sides to hold the plant upright.
- **Indeterminate** tomatoes keep growing and bearing as long as conditions stay warm enough. They are essentially a vine and produce the most fruit when carefully pruned and trained vertically.

All tomatoes produce suckers above every leaf. Left unpruned, each sucker will grow into a shoot with leaves and fruit. If every sucker remains, all those shoots, leaves and fruit compete with each other for food, light and water. By limiting the number of suckers and leaves, plant energy is directed to the remaining shoots for optimum yield and quality. It is best to remove suckers while still small to direct plant energy upward.

As tomatoes grow taller their lower leaves become unnecessary. Removing the lower leaves allows for better air circulation for less disease pressure. The pruning methods described on pages 2-3 will explain how many lower leaves to remove.

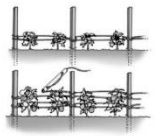


Training and Pruning Determinate Tomatoes

(ex. Red Bounty, Red Deuce*, Celebrity, Primo Red*, Volante)

** leaf mold resistant variety*

Training Determinates

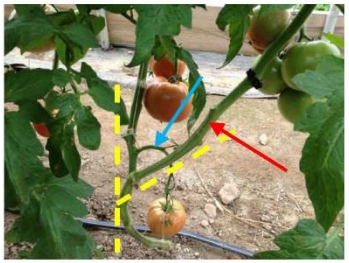


Provide horizontal support

1. Set the plants at the proper spacing
2. Set a 5' stake into the ground between every 2 plants (see diagram)
3. Weave the twine around and between each plant in a Figure 8 pattern, starting at 8" from the ground and repeating every 6-8" as the plants grow. The plants will grow to about 4' tall so continue adding twine to provide even support for the plants.
4. This is called the basket weave, the Florida weave, and/or the stake and weave system.

Pruning Determinates

The Strong Y (see photo, right)



1. Remove the leaves up to the first flower cluster (blue arrow).
2. Leave the sucker just under the first flower cluster (red arrow) and remove all suckers below that point.
3. The stem should now look like the letter 'Y' (yellow dotted line in Figure A).
4. No more pruning is required. Experienced growers will do some thinning through the season but newer growers should focus on training by adding more rows of twine as the plants grow.

Tip: Removing Lower Leaves

A handy method of removing leaves is to first bend the leaf upwards and then downwards. Listen for a soft 'snap' with each movement. If the leaves only bend and do not snap, use a sharp knife to cut them off close to the stem.

Snapping is preferred to cutting so the leaf can separate at its natural point of attachment. Use caution to not tear off the leaves which may leave a ragged stump or tear that will be slow to heal over. A clean snap will seal off quickly.

The photo (right) shows bare stems with plenty of air circulation and no leaves touching the ground.

Training and Pruning Indeterminate Tomatoes

(ex. Arbason, Big Beef, Geronimo*, most Heirlooms, Panzer*, Rebelski*)

** leaf mold resistant variety*

Training Indeterminates

Provide vertical support

1. Decide on 1 or 2 leaders per plant.
   Heirlooms and grafted plants do best with 2 leaders, newer growers find 2 leaders easier to manage. Hybrids do well as a single leader.
2. Set the plants at the proper spacing.
   Allow 24" in-row spacing between each leader.
3. Drop a line down from the overhead support, 1 line for each leader.
4. Use a tomato clip to fasten the line below the first leaves, add clips every 6-12" up the stem. Be sure the clip holds the line in its hinge.
5. Ensure the structure can bear the weight of the crop without bending the frame.
6. Consider running the lines from a spool so the plants can be lowered as they grow to facilitate harvesting. Several models are available.

Pruning Indeterminates

1. For a single leader, remove all suckers and all leaves below the first flower cluster. The result is one long vine-like leader with no side shoots.
2. For a double leader, establish **The Strong Y** as described on page 2. Each arm of the Y will become a leader, 2 leaders per plant.
3. Maintain the leaders throughout the entire growing season by continually pruning off all suckers that form. This will need to be done at least weekly , especially during the first 6 weeks.
4. Continue removing lower leaves as each fruit cluster is harvested. Remove leaves gradually, a few each week, rather than too many at once.
5. When using a spool, lower the vines as the lowest fruit clusters are harvested; this brings the ripening fruit down to a level easier to reach for harvesting and pruning. The vines will bend as they are lowered.

Some varieties resistant to Leaf Mold

New, resistant varieties are introduced each year. This is partial list is current as of 2015.

Cherry/Grape Type

Favorita
Golden Sweet
Pareso (grape)
Picus (determinate, Roma)
Sakura
Sunpeach (pink)
Sweet Chelsea
Sweet Elite (grape)
Sweet Gold (yellow)
Sweet Hearts
Sweet Treats (pink)
Viva Italia (derminate, pear)

Salad/Slicers

Bellini
Beorange (orange)
Big Dena
Caramba
Clermon (truss type)
Climstar (cluster)
Frederick (compact)
Geronimo
Margold
Panzer
Pink Cupcake
Pink Wonder
Primo Red (determinate)
Poseiden (pink)
Rally (determinate)
Rebelski (determinate)
Red Deuce (determinate)
Rossini
Tomimaru Muchoo (pink)
Trust

Some popular varieties that are susceptible to leaf mold

(this is a partial list, not comprehensive)

Arbason	Big Beef
Brandywine and heirlooms	
Estiva	Pruden's Purple
Red Bounty	Striped German
Sun Gold	Sun Sugar
Sweet 100	Volante

Some Useful Websites:
http://www.hort.cornell.edu/hightunnel
http://vegetablemdonline.ppath.cornell.edu/

Prepared by Amy Ivy, Eastern NY Commercial Horticulture Program. March 2014, revised July 2015
All photos by A. Ivy

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http://www.nnyagdev.org/
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BEST MANAGEMENT PRACTICES
IN HIGH TUNNEL PRODUCTION

Leaf Mold

Leaf mold is a fungus disease of tomatoes that has been increasing across New York State in recent years. It is favored by high humidity and is therefore seen in greenhouse and high tunnel production but rarely in field production. It spreads rapidly from plant to plant, covering leaves with lesions and defoliating plants which severely reduces yield.

Leaf mold is caused by the fungus *Fulvia fulva*. It was formerly called *Cladosporium fulvum* and as of 2013 mycologists use the name *Passalora fulva*. It is also called 'brown leaf mold' or simply 'leaf mold'. Gray mold (*Botrytis cinerea*) is a different pathogen, not to be confused with leaf mold (*Fulvia fulva* or *Passalora fulva*).

Prevention and Control

Because high humidity (>85%) favors this disease, practices that increase air circulation throughout the tunnel including ventilation, spacing, pruning and training can help. Spores are carried on air currents, tools, worker clothing and seed, and spread quickly throughout the tunnel. The fungus overwinters on crop debris and in the soil and can persist for at least one year without a host crop. In spite of thorough sanitation at the end of the season, once a tunnel has had a leaf mold infestation, it is very likely to be infested the following year.

Fungicide sprays, including copper, have not proven effective in stopping the spread although more research needs to be done to consider other materials. Sporulation occurs on the underside of the leaves making it difficult to achieve adequate spray coverage. Currently, once a tunnel becomes infested the best practice is to use resistant varieties.

Grafting onto vigorous, root disease resistant rootstocks is a practice that is being more widely adopted by high tunnel growers. But because leaf mold is a foliar disease, not a root disease, grafting does not have an impact on the scion's resistance to leaf mold.

Resistant Varieties – the best approach

There several tomato varieties that show resistance to leaf mold (see page 4) but the pathogen continues to mutate into new races. New varieties are developed each year with further resistance. Planting several different leaf mold resistant varieties will help reduce grower risk from this disease.

None of the heirloom varieties such as *Brandywine*, *Pruden's Purple* and *Striped German* is resistant to leaf mold.

Photo: *Resistant variety 'Rebelski' on left, susceptible variety 'Sun Gold' on right.*

Leaf Mold - early symptoms

Early leaf mold symptoms: yellow spots on surface of leaf.

Typical early leaf mold lesions: yellow on top of leaf, brown and sporulating on underside of leaf.

Properly space, prune and train the crop to contain excess growth, keep aisles clear.
Determinate on left
with stake and weave system.
Indeterminate on right
with single leader system.

Tips

for increasing air circulation and air movement in tunnels to discourage leaf mold and other fungal diseases

Roll-down or roll-up side walls, high straight side walls. Large doorways on both ends, gable end vents would also help.

Leaf Mold Look-Alikes

Early blight - typical target lesion

Septoria leaf spot - distinct dark spots followed by leaf yellowing

Gray mold on leaf causes tip dieback

Late blight - large lesions expand rapidly with no distinct margins

Bacterial speck - small, dark distinct spots, with yellow margins

Magnesium deficiency - yellowing between veins, yellow areas turn brown with time

These are NOT Leaf Mold

Some Varieties Suited to High Tunnels

Note: Good air circulation from adequate spacing and ventilation will help reduce PM pressure. When choosing varieties for high tunnel production look for all three qualities when possible: parthenocarpic, gynoecious and PM resistant.

Key to abbreviations in the list below: G--gynoecious, P-parthenocarpic, PM-powdery mildew resistant

Pickling
Excelsior (G, P, PM)
Vertina (P, PM)

Snack or Cocktail (less than 4" long)
Iznik (G, P, PM)
Piccolino (P, PM)
Unistars (G, P, PM)

Beit Alpha
Manar (P, PM)
Manny (P, PM)
Socrates (P, PM)

Slicing or medium, 4-8" long
Corinto (G, P, PM)
Diva (G, P, PM)
Katrina (P, PM)
Lisboa (P)

Extra long types (more than 8" long)
(this group may develop misshapen fruit if pollinated)
Sweet Success 12" long (G, P)
Taurus 8-9" long (P, PM)
Tyria 14" long (G, P, PM)

Useful Websites:

Cornell High Tunnels: http://www.hort.cornell.edu/hightunnel
Team High Tunnel Websites: http://cvp.cce.cornell.edu/greenhouse_tunnels.php
And http://enych.cce.cornell.edu/greenhouse_tunnels.php

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BEST MANAGEMENT PRACTICES
IN HIGH TUNNEL PRODUCTION

Cucumbers

Cucumbers are an excellent high tunnel crop for spring, summer and fall production in New York State. Grown vertically, cucumbers take advantage of the space and light offered by a high tunnel. Cucumbers grown in this environment are of higher quality with higher yields. Very fast growing and yielding, they fit into crop plans that include winter greens easier than tomatoes, peppers or eggplants.

High tunnel cucumbers include pickles, slicers, cocktail, English or Asian varieties. Selection of type must meet both market demands and the horticultural demands of tunnel production. Cucumbers grown inside do present additional labor and pest management challenges, but can be grown at a profit when properly marketed.

Types of Cucumbers

The most important decision in growing high tunnel cucumbers is choosing an appropriate variety. There are numerous cucumber varieties suitable for high tunnel production from pickles, to slicers to seedless to Asian types. The type of cucumber grown depends on market demand; some ethnic populations may have preferences for European, Middle Eastern or Asian varieties. American slicing cucumbers have a broad appeal, but are not as easy to differentiate from field grown crops. Pickling types can be popular, and will require additional labor. Since high tunnel cucumbers are a heavy yielding crop, it is important to know the market will receive the product prior to planting.

Within any one of the many subcategories of cucumbers that can be grown we strongly recommend parthenocarpic varieties for high tunnels, which do not require pollination. Gynoecious varieties produce (nearly) all female flowers, increasing total fruit set and are the most appropriate for high tunnel production. Beit Alpha cucumbers are thin skinned varieties originating in Israel and perform very well in tunnels.

We suggest caution with longer greenhouse cucumbers (sometimes called English or Dutch) in high tunnels. As this is a passively ventilated structure, there is considerably more wind and pollinator visitation than in controlled environment greenhouses. These factors lead to misshapen fruit. Longer cucumbers may require additional fruit thinning to balance shoot/fruit growth. Powdery Mildew resistance is as important as parthenocarpy for tunnel production. Powdery Mildew is a disease that is particularly severe within the tunnel growing environment, and varietal resistance is an essential management tool. Varieties with Powdery Mildew resistance may be listed as PMR or PMT in catalogs.

Varieties best suited to high tunnels are:

- Parthenocarpic
- Gynoecious
- Powdery Mildew resistant

(see page 4 for some suggested varieties)

Managing Cucumbers in Tunnels

Provide Adequate Space

Cucumbers produce prolifically in high tunnels. For the greatest yield and efficient management provide plenty of space. Set the rows at least 4 feet apart, up to 6 feet. The plants can either be set 12" apart in a single row or 24" apart in a double, staggered row.

Set out young transplants, using care to not disturb the roots. Covering the beds with black plastic 1-2 weeks before planting will warm the soil, slow moisture loss and suppress weeds.

Provide Support

To make the best use of the valuable space In a tunnel or greenhouse cucumbers are given a mesh trellis to climb up or are trained to a single leader, similar to the way indeterminate tomatoes are trained.

Pruning to a single leader works only on parthenocarpic varieties because they produce a flower, a leaf and a shoot all at the same node, making it simple to prune out the shoots and leave the flowers. Regular field type cucumbers (Marketmore 76, Dasher, etc) produce their flowers along the runner shoots. Training field cucumbers to a single leader results in pruning off their flowering shoots, so no fruiting is possible.

It may seem as though training cucumbers to a single leader wouldn't be worth the time and effort. But in a recent study comparing yield and labor between the two methods of support, the single leader plants yielded 20% more fruit than the trellised plants of the same variety. And the overall labor including planting, trellising and harvesting differed by only 5% between the two methods, with the single leader plants actually taking less labor.

Comparative research study 2014

(3 replications of each treatment, same variety)

	Single Leader	Mesh Trellis
Total labor	14.48 hrs	15.23 hrs
Yield	1275 fruits (38.6 per plant)	1014 fruits (30.7 per plant)

Trial comparing two methods of training cucumbers

Water and Fertility

Cucumbers are a water intensive crop. In order to achieve maximum yield and uniform fruit quality, daily watering is recommended. An automatic timer helps ensure consistent soil moisture which leads to properly filled cucumbers. Many growers use two drip tapes beneath plastic mulch to ensure uniform and complete soil moisture.

As a fast growing and heavy yielding crop, tunnel cucumbers have a high fertility requirement. Soil testing prior to planting is important to assess phosphorus, potassium, calcium and pH levels. These can then be adjusted prior to planting with either organic or conventional amendments. Nitrogen requirements will likely exceed 100 lbs per acre. The delivery of this nitrogen can be spaced out over the life of the crop with fertilizer injection in the irrigation system. Slightly acid soil and water pH of 6.0-6.5 is optimum for nutrient uptake. In-season foliar testing allows for further adjustments and can reveal deficiencies before visual symptoms or yield loss occurs.

Pests and Problems of Cucumbers in High Tunnels

High Tunnel cucumbers experience more pest pressure than other tunnel crops. The primary pests are two-spotted spider mite, thrips, squash bug and striped cucumber beetle. Excellent biological control options exist for spider mites and thrips. In Cornell research, predatory mites including *Amblyseius cucumeris* and *californicus* have been successful at managing these pests when released early in crop cycle.

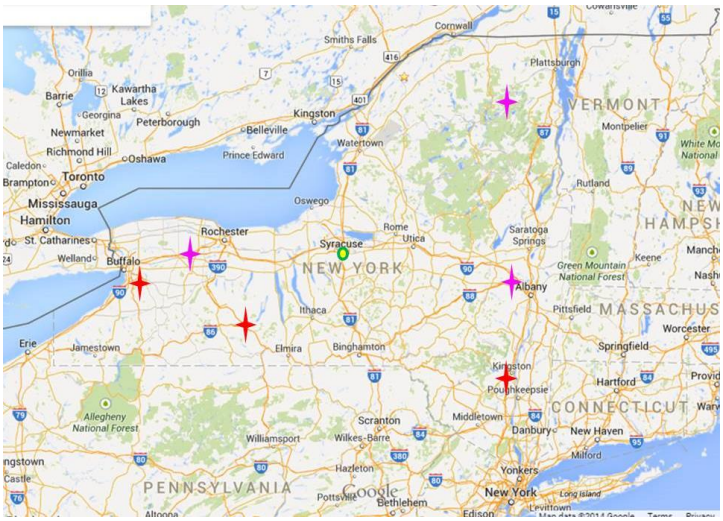
Spider Mites and Thrips are so common in high tunnel cucumbers that releasing prior to observable damage is advised. There are no commercial biological controls for squash bug and striped cucumber beetle. Screening of side walls can reduce cucumber beetle infestations. There are insecticides available for the management of these pests, but study labels closely to be sure their use is not prohibited in greenhouses. For example, carbaryl (Sevin) is widely used in field production but is prohibited in greenhouse/tunnel production. New products are released each year so check current recommends and labels for the latest information.

Bacterial wilt is spread by the feeding of cucumber beetles so controlling these insects is essential to slow this disease. Powdery mildew (PM) thrives under the more humid conditions in a tunnel. Choose PM resistant varieties whenever possible but realize that resistance can be variable. Effective control with fungicides is challenging in a tunnel, focus on resistant varieties and check for new releases from seed suppliers each year. See page 4 for a partial list of PM resistant varieties suitable for high tunnels.

Cucumber beetle

Bacterial Wilt

Powdery Mildew



Key to Locations of Winter High Tunnel Schools

2013 winter school locations

2014 winter school locations

Syracuse Expo January '15

Winter High Tunnel School

Batavia, NY December 5, 2013

Field Staff Training June 5-6, 2014

Included talks by staff and experienced growers as well as a day of farm visits to see a variety of tunnels in production

Photos showing examples improvements case study growers have made in management practices

The first set of photos shows improvements Grower A made from his first to second year in the project in terms of training and pruning, fertility management, weed control and irrigation management.

(Left – August 8, 2013 Right – August 9, 2014)

The second set of photos shows improvements Grower H made from the first to second year in terms of addressing external and internal drainage issues.

(Left – June 17, 2013 Right – June 9, 2014)

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Project 7
Survey of Streptomycin-Resistant Erwinia Amylovora (Fire Blight) in New York to Improve Control Options for Growers

Project Summary

Background for the initial purpose of the project:

Given the lack of viable chemical and cultural management options for fire blight, streptomycin has been used widely in the United States for over 50 years to provide effective and necessary control of E. amylovora outbreaks. However, reports of streptomycin resistance have raised concerns about the sustainability of this antibiotic for fire blight management. The first reports of streptomycin resistance occurred in California in 1971, followed by Washington and Oregon in 1972. Since these discoveries, streptomycin resistant (SmR) E. amylovora has become established in apple growing regions along the western coast of the United States and in certain apple growing regions of Missouri and Michigan. SmR isolates of E. amylovora were not observed in New York until 2002. In this instance, two SmR isolates of E. amylovora, NY17.1 and NY17.2 were recovered from fire blight outbreaks in two adjacent orchards in Wayne County. Eradication efforts, which included prompt removal of trees, were put in place in order to contain and destroy SmR E. amylovora infected plant materials and prevent spread of these bacteria to other orchards.

Motivation for this project:

Since the discovery and eradication of SmR E. amylovora in New York in 2002, there have been limited investigations. Informal surveys from 2004 to 2006 were conducted for SmR E. amylovora in areas of western New York on samples where fire blight developed. These surveys failed to detect SmR E. amylovora, leading to the belief that eradication efforts were successful in containing the outbreak in New York. Despite these assurances, apple producers raised concerns about the effectiveness of streptomycin every year, and little is known about the prevalence of SmR E. amylovora in New York beyond the sites of original detection in 2002. Moreover, the genetic determinants responsible for resistance would need to be characterized for any new isolates of SmR E. amylovora recovered from New York apple orchards. In order to address these knowledge gaps, our goals were to examine fire blight outbreaks in New York apple orchards from 2011 to 2014 for the presence SmR E. amylovora, and characterize determinants of streptomycin resistance for any SmR E. amylovora isolates recovered. The resulting information would help New York apple producers better assess the threat of streptomycin resistance development in E. amylovora, and adjust antibiotic use practices for resistance management.

Previously SCBGP or SCBGP-FB funding:

This project was not based on a previously funded SCBGP or SCBGP-FB project.

Project Approach

Objective 1: *Determine the prevalence of SmR E. amylovora at previously confirmed sites and new orchard sites by monitoring and sampling for FB infections, and assaying resulting E. amylovora strains for SmR.*

Task/Project activities and progress/accomplishments for each task are listed below.

1. Survey orchard locations with previously confirmed cases of SmR E. amylovora, and new and existing orchard plantings with suspect trees or those streptomycin control failures and fire blight symptoms for the present of SmR E. amylovora.

From 2012 to 2015, samples of fire blight were collected from outbreaks at nurseries and production orchards across the apple growing regions of New York State. Collection efforts took place as a cooperative effort between the New York State Agricultural Experiment Station, Cornell cooperative extension, the Lake Ontario Fruit Program, New York State Integrated Pest Management, and Eastern New York Regional Fruit Program. Sample collection efforts were largely driven by grower and cooperative extension reported instances of fire blight outbreaks within individual orchards of relevance to production sustainability. Samples consisted of blighted blossom clusters, shoot blight of first and second year scion, and blighted rootstocks.

From 2011 to 2014, samples were collected from a total of 80 commercial orchards with fire blight outbreaks. The majority of the samples were from orchards in Wayne, Monroe, Niagara, Ontario, Orleans and Tompkins counties in Western New York. By comparison, only 19 of the 591 samples were from Albany, Clinton, Orange, Suffolk, and Ulster counties in Eastern New York. Of the 591 samples collected, 97 were blighted blossoms, 415 were shoot blight of first or second year scions, and 74 were blighted rootstocks. In addition, there were 5 samples collected from the coleopteran Xylosandrus germanus or its galleries that appeared to be oozing with fire blight. Across all years, samples were predominantly from cultivars 'Gala', 'Ginger Gold', 'Honeycrisp', 'Snapdragon', and 'Rubyfrost'. From the samples, 1,384 bacterial isolates were obtained and 1,280 were confirmed to be E. amylovora. Single colonies of isolates produced the characteristic cratered appearance on CG medium (Crosse and Goodman 1973), and when PCR was performed using primers AJ75 and AJ76 (McManus and Jones 1995), all isolates produced an 840 bp band, indicative of the presence of the ubiquitous, nonconjugative plasmid, pEa29.

Of the 1,280 isolates, 34 displayed a streptomycin resistant phenotype on CG medium in that a zone of inhibition failed to develop around filter papers discs with streptomycin concentrations of 100 ug/ml. For two of the 34 isolates, 306a and 189b, a zone of inhibition failed to develop around filter papers discs with streptomycin concentrations of 2500 ug/ml (Table 2). All 34 streptomycin resistant isolates of E. amylovora isolates and Ea273 were found to produce necrotic lesions and bacterial ooze within 48-96 hours on immature pear fruits confirming pathogenicity (Table 1).

Of the 34 SmR isolates of E. amylovora, 20 were recovered from orchards in Wayne County and 5 were from orchards in Ontario County (Table 1). The remaining isolates were recovered from orchards in Monroe, Orleans, Tompkins, and Niagara counties in Western New York (Fig. 1). Isolates of SmR E. amylovora were recovered from 20 cultivars of apple with three or more SmR isolates recovered from 'Idared', 'Rubyfrost', and 'McIntosh' apples. Nearly all of the isolates (28) were obtained from shoot blight that developed in the current year's scion tissue (Table 1). Three isolates were obtained from blossom clusters, two from rootstock blight samples, and one was obtained from the coleopteran Xylosandrus germanus.

Objective 2: *Determine the genetic nature of SmR (i.e. chromosomal or plasmid-borne) for all SmR E. amylovora isolates identified. This will help to ascertain the origin of the outbreaks and sources of spread of SmR E. amylovora in NY.*

Task/Project activities and progress on each activity are listed below.

1. Identification of the strA/strB gene pair in streptomycin resistant E. amylovora isolates.

   All streptomycin resistant isolates and the SmS isolate Ea273 (negative control) were tested for the presence of the strA/strB gene pair using primers previously developed by Russo et al.

(2008). PCR products were visualized using gel electrophoresis on a 1% agarose gel. For a subset of isolates, PCR products were then sequenced at the Cornell Biotechnical Resource center in Ithaca, NY using an ABI 3730xl capillary sequencer (Applied Biosystems).

Amplification of the Tn5393 region containing the *strA/strB* gene pair revealed the presence of a 406 bp and 403 bp band in 32 of the SmR isolates of *E. amylovora.* These bands were not present for SmS isolate Ea273 and the two streptomycin resistant isolates 306a and 189b, which grew in the presence of 2500 ug/ml streptomycin. Sequencing of these regions confirmed the identity of the 406bp and 403bp bands to be the *strA* and *strB* genes previously described for streptomycin resistant isolates of *E. amylovora.*

2. S12 ribosomal protein rpsL gene identification and sequencing in streptomycin resistant E. amylovora isolates.

   Isolates confirmed to have a streptomycin resistance phenotype that would allow them to grow in the presence of 2500 ug/ml streptomycin sulfate were examined for the presence of mutations at codon 43 in the *rpsL* gene. Using primers previously developed by Russo et al. (2008) a portion of the *rpsL* gene containing codon 43 was amplified and sequenced. PCR products were purified for sequencing using a Zymo DNA Clean & Concentrator kit (Zymo Research). Purified products were sequenced at the Cornell Biotechnical Resource center in Ithaca, NY using an ABI 3730xl capillary electrophoresis instrument (Applied Biosystems).

   Amplification of the region containing codon 43 of the S12 ribosomal protein yielded a 212 bp band for all 34 SmR isolates of *E. amylovora* and Ea273, the SmS control. Sequencing of the 212 bp band confirmed the identity of the 212 bp region to be a portion of the *rpsL* gene of *E. amylovora*. Sequences of each resistant isolate were compared to the sequence of the sensitive isolate Ea273. Two isolates, 306a and 189b, were found to have a point mutation at codon 43 (Table 2). In both isolates, this mutation resulted in an amino acid change from lysine to arginine (K43R). The remaining 32 isolates and the SmS isolate Ea273 did not have a mutation present in this region.

Protocols entitled, 2013, 2014, and 2015 Guidelines for Fire Blight Management in New York was development and delivered to fruit growers at the Empire State Fruit and Vegetable Expos in January of 2013, 2014, and 2015 respectively. This protocol included management practices on avoiding streptomycin resistance and avoiding bud-infected tress, which were developed from the scientific information generated by the products of the proposal.

Finally, project outcomes were incorporated in the management guidelines presented in the 2012, 2013, and 2014 Cornell Pest Management Guidelines for Commercial Tree Fruit Production.

Significant contributions and role of project partners:

- Kerik Cox was responsible for project oversight, preparation of reports, the writing of management protocols, and presentation of research outcomes at stakeholder meetings and educational schools. Cox was also responsible for ensuring that sample collectors and lab personnel collected and processed samples appropriately and that data was analyzed and formatted for presentation at the stakeholder meetings and fruit schools.

Goals and Outcomes Achieved

Activity completion as related to project goals:

As described in the original grant application, the first goal of the project was to determine the prevalence of streptomycin resistant *Erwinia amylovora* at sites previously confirmed to have SmR E.

amylovora, and new orchard sites by monitoring and sampling for fire blight infections, and assaying resulting strains for streptomycin resistance. The second goal was to determine the genetic nature of SmR (i.e. chromosomal or plasmid-borne) for all SmR E. amylovora isolates identified. This would help to ascertain the origin of the outbreaks and sources of spread of SmR E. amylovora in NY.

First goal: *Determine the prevalence of SmR E. amylovora at previously confirmed sites and new orchard sites by monitoring and sampling for FB infections, and assaying resulting E. amylovora strains for SmR.*

For this goal, we actually accomplished the following activities:

1. We collected 591 samples from 80 commercial orchards from 11 counties in NY
2. From these samples we examined 1280 isolates to confirm the isolation of *E. amylovora* and the presence of streptomycin resistance in vitro

Second goal: *Determine the genetic nature of SmR (i.e. chromosomal or plasmid-borne) for all SmR E. amylovora isolates identified.* This would help to ascertain the origin of the outbreaks and sources of spread of SmR E. amylovora in NY.

For this goal, we actually accomplished the following activities:

1. We examined the 34 isolates with streptomycin resistance for the presence of the *strA/strB* gene pair on the transposable element Tn5393.
2. We sequenced the S12 ribosomal protein rpsL gene for all 34 streptomycin resistant isolates to look for the present of mutations conferring streptomycin resistance.

Conveying completion of goals via baseline data and set targets:

In the original proposal, our **benchmark** was to resurvey orchards with streptomycin resistance in 2011 and provide **baseline data** on the sites at risk for streptomycin resistance in western NY. Our baseline data indicates that both sites with streptomycin resistant fire blight and those neighboring sites with SmR E. amylovora are not necessarily at risk from SmR E. amylovora since SmR E. amylovora was not at any locations in 2014 and 2015. However, growers should take care with antibiotic use in Western NY as strains of SmR E. amylovora may still emerge in later years resistance management isn't practiced. Our **performance target** was to provide survey information only for growers with a history of problems or those in areas near outbreaks of SmR E. amylovora. Indeed, using our **performance measure** of operations surveyed, we have gone beyond the seven orchards with previously documents problems with SmR E. amylovora and those in the region near the outbreaks. We have surveyed more than 80 orchards from 11 counties across all production regions of the state.

Beneficiaries

The group who stands to benefit the most from this proposal work are the NY apple growers as nearly all apple growers are continually replanting to high density plantings (>1000 trees/A) of apple varieties, all of which are sensitive to fire blight. All apple growers must manage fire blight with bloom time applications of antibiotics or risk complete loss. Information on prevalence of SmR E. amylovora the also stands to benefit growers in regions outside of those near previous SmR E. amylovora outbreaks as they know that they can continue to use streptomycin responsibly without risk.

Loss of newly planted trees to fire blight infection that develops from asymptomatic infection is especially costly to growers. New trees for planting typically cost **$8-15 USD/tree**, which can result in astronomical monetary as growers plant **10s to 100s acres** of apples at densities often exceeding **1,000 tree/A.** For example, at $7/tree and 1250 tree/A, losing a single acre due to contaminated budwood would

cost nearly $8,750 in trees alone. Such losses are not uncommon as epidemics in MI and WA (and now NY in 2015) have resulted in 100s of acres lost to fire blight. In addition to trees, growers make considerable investment in land preparation, (trellising), and orchard maintenance. They lose not only the trees, but also the possibility for production for the several years until replacement trees can be established. When all of these economic factors are considered, the monetary loss per acre can amount to nearly tens of thousands of dollars. Since all successful growers are continually planting and replanting portions of their operation, the outcomes of this work would allow growers to avoid antibiotic use practices that would lead to these costly losses.

Lessons Learned

From the completed activities of the project we have learned several lessons:

1. Streptomycin resistant fire blight is restricted to western NY in areas near the original outbreaks.
2. Apple production regions in eastern NY do not have SmR E. amylovora, and can continue to use streptomycin responsibly.
3. From 2014 to 2015, SmR E. amylovora hasn't been found at any orchards in NY. Hence, resistant management practices may have eliminated local SmR E. amylovora strains for the time being.
4. Nearly all of the SmR E. amylovora strains have the *strA/strB* gene pair on Tn5393, which is predominant streptomycin resistant genotype found in Michigan.

Additional Information

Presentations

Information on the scientific outcomes of the proposal and the management recommendations from this work were presented to 84 growers at Empire State Fruit and Vegetable Expo. January 22, 2014. Similarly, information on the management of strep resistant *Erwinia amylovora* (SmR Ea) was presented to 58 growers at the Hudson Valley Commercial Fruit Growers' School on Feb. 10, 2014, and to 66 growers at the Upper Hudson / Champlain Commercial Tree-Fruit School. Feb. 11, 2014. Additional recommendations for managing the spread of SmR Ea and preventing transmission of *Erwinia amylovora* in latent bud wood were delivered to 125 growers with protocol handouts describing final outcomes of the project at the Lake Ontario Fruit Team Petal Fall/Thinning Meeting on May 29 2014 and Summer Tour on July 24th 2014.

Publications

Publication of results and SR Ea recommendations in Scaffolds, NY Fruit Quarterly, County Extension Newsletters, on the Fruit and Berry Website and in Fruit FAX. & Publication of results and recommendations in Scaffolds, NY Fruit Quarterly, County Extension Newsletters, on the Fruit and Berry Website and in Fruit FAX.

Cox, K.D., Breth, D., Borejsza-Wysocka, E., and Aldwinckle, H. S. 2013. The presence of the fire blight bacterium Erwinia amylovora in asymptomatic apple bud wood: A potential threat to new apple plantings. Phytopathology 103:S2.31.

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Bekoscke, K.A., Breth, D., Kuehne, S., Borejsza-Wysocka, E., Aldwinckle, H.S., Villani, S., and Cox, K.D. Status of Streptomycin Resistant Fire Blight in New York Orchards. New York Fruit Quarterly. 22(3):5-8.

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Cox, K.D., and Rosenberger, D.A. 2015. Hot times: Guidelines for Fire Blight Management in New York in 2015. Scaffolds 24(6): 4-8.

Cox, K.D., and Rosenberger, D.A. 2015. Foreign Lesion: Where is strep resistance fire blight in New York? Scaffolds 24(12): 5-7.

Table 1. Location sites with streptomycin resistant (SmR) *E. amylovora*

Year	Isolate	County	Cultivar[a]	Tissue[b]	pEa29[c]	Pathogenic[d]	*stA/strB*[e]	*rpsL*[f]
2011								
	161	Wayne	'Idared'	Shoot	+	+	+	-
	162	Wayne	'Rome'	Shoot	+	+	+	-
	173	Wayne	'SnapDragon'	Shoot	+	+	+	-
	174	Wayne	'RubyFrost'	Shoot	+	+	+	-
	175	Wayne	'McIntosh'	Shoot	+	+	+	-
	176	Wayne	'Red Delicious'	Shoot	+	+	+	-
	177	Ontario	'Idared'	Shoot	+	+	+	-
	178	Monroe	'Idared'	Shoot	+	+	+	-
	179	Wayne	'Rhode Island Greening'	Shoot	+	+	+	-
2012								
	316	Monroe	'RubyFrost'	Shoot	+	+	+	-
	301	Niagara	'SweeTango'	Shoot	+	+	+	-
	230	Ontario	'Idared'	Shoot	+	+	+	-
	313	Ontario	'Twenty ounce'	Rootstock	+	+	+	-

	306a	Ontario	'Lady'	Shoot	+	+	+	-
	306b	Ontario	'Lady'	Shoot	+	+	-	K43R
	249	Orleans	'Aztec Fuji'	Blossom	+	+	+	-
	278	Orleans	'Cameo'	Shoot	+	+	+	-
	189	Wayne	'Gingergold'	Shoot	+	+	+	-
	254	Wayne	'M.26 RS'	Shoot	+	+	+	-
	292	Wayne	'Idared'	Shoot	+	+	+	-
	189a	Wayne	'Gingergold'	Shoot	+	+	-	K43R
	189b	Wayne	'Gingergold'	Shoot	+	+	+	-
	2992d	Wayne	'RubyFrost'	Shoot	+	+	+	-
	3002d	Wayne	'Gala'	Shoot	+	+	+	-
	3002e	Wayne	'Gala'	Shoot	+	+	+	-
2013								
	465	Monroe	'Royal Court'	Blossom	+	+	+	-
	321	Orleans	M.9	Rootstock	+	+	+	-
	436	Tompkins	'McIntosh'	Blossom	+	+	+	-
	439	Tompkins	'McIntosh'	Shoot	+	+	+	-
	330	Wayne	'Jonagold'	Shoot	+	+	+	-
	333	Wayne	'Jonagold'	Shoot	+	+	+	-
	345	Wayne	'Pink Lady'	Shoot	+	+	+	-
	508	Wayne	'Idared'	Shoot	+	+	+	-
	374	Wayne	'Macoun'	*Xylosandrus germanus*	+	+	+	-

a. *Malus* × *domestica* cultivar scion or rootstock from which the tissue sample was collected
b. The type of tissue from which the isolate was collected.
c. The presence of the plasmid Ea29: (+) present or (-) absent
d. Pathogenicity on immature pear fruit: (+) isolate produced necrosis and ooze or (-) isolate produced neither ooze nor necrosis
e. The presence or absence of the *strA/strB* gene pair: (+) present or (-) absent
f. Presence of the K43R mutation in the *rpsL* gene: (K43R) present or (-) absent

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Project 8
Spotted Wing Drosophila: New Threat to Profitability of Fruit Crops in New York State

Project Summary

Spotted wing drosophila (SWD), *Drosophila suzukii* represents a serious challenge for fruit growers in New York and elsewhere. Unlike other fruit flies, this species has the capacity to lay its eggs in ripe, marketable, soft-skinned fruit. Later maturing berries, such as blueberries, fall raspberries and day-neutral strawberries, appear to be especially vulnerable, although stone fruit, such as peaches and sweet cherries, and grapes are potentially also at risk. Serious economic losses, estimated at close to $5 million, were reported for berry crops and grapes in NY in 2012. In that year, some producers of fall raspberries prematurely ended the harvest season due to infested fruit. The fear of the economic consequences of selling infested fruit has sometimes led growers to pre-emptive and excessive use of insecticides, disrupting well-established IPM programs. This level of emphasis on chemical management increases costs, hastens the development of resistance in SWD to insecticides, has negative impacts on beneficial insects and the environment, and increases the risk of worker and consumer exposure to insecticides.

At the start of this project, our knowledge of the biology and phenology of SWD was limited. Based on initial research, SWD appears to overwinter as adult flies in sheltered areas, probably at relatively low numbers in New York. However, we did not have a lot of information on seasonality of SWD in New York, including which crops were at greatest risk, to what extent SWD utilizes wild hosts for reproduction, which chemical control alternatives were the most effective, and whether wild hosts or other landscape features near farms influence risk of infestation. The goal of this project was to address these knowledge gaps. This information is necessary to develop more sustainable approaches involving reliable monitoring and effective management based on cultural, biological and chemical tactics.

Project Approach

This project addressed five research objectives to better understand the biology and management of spotted wing drosophila (SWD) in New York. Our approach to addressing these objectives and our findings are reported below by related objectives.

Objective 1: *Assess SWD adult abundance and larval infestations in small fruit crops through growing season and Objective 2, test alternative lures for monitoring adult SWD.*

We assessed seasonal pattern of SWD population dynamics and fruit infestation in different small fruit crops in 2013 and 2014. We also tested alternative lures in traps for monitoring adult SWD for its potential as a decision tool for grower, with specific focus on blueberries and summer raspberries. Berry crops potentially at risk in New York include June-bearing strawberry, summer raspberry, blueberry, fall raspberry and day-neutral strawberry. To assess fruit infestation in these crops, we collected ripe, but otherwise undamaged fruit during the 2013 and 2014 field season from different farms in the Finger Lakes and Lake Ontario Regions of New York. Timing of when fruit becomes ripe appears to be the key risk factor. Fruit that ripens before mid-July mostly escaped injury. Indeed, we never reared any SWD from June-bearing strawberry. Berry crops that ripened in early to mid-July (summer raspberry and early maturing blueberry cultivars), mostly escaped infestation. Berry crops that ripened in later July, August and September were at the greatest risk for infestation and serious economic impact.

During this project we conducted field research comparing the efficacy of different lures for monitoring adult SWD in relation to fruit infestation. Earlier studies had shown that apple cider vinegar (ACV) as a lure in a trap did capture SWD and a large number of other species of small insects, but generally not before infestation of fruit started. Hence, it was not considered that useful for growers. We compared different alternative lures at multiple blueberry plantings and summer raspberry plantings and found that a lure made from water, sugar, yeast and whole wheat (fermenting bait) placed in a separate receptacle and

floated in a drowning solution caught the most SWD and earlier in the season than other lures. In 2014, we found that for 5 out of 6 sites, adult SWD were captured in traps baited with this fermenting lure 1 to 2 weeks prior to the first evidence of fruit infestation thereby providing early warning of infestation risk. In the sixth site, we captured the first adult the same week we detected low infestation levels. Although encouraging, this bait does capture many non-target insects, including other species of *Drosophila*, making it challenging for non-experts to process and correctly identify SWD. Thus, more selective lures would allow more growers to use this monitoring tool to help them make management decisions.

Objective 2*: Evaluate wild plants near fruit farms as potential hosts for SWD and relationship to crop infestation.*

We assessed potential reproductive hosts of SWD in woods adjacent to 8 farms in central NY during the 2013 field season through December. We found that bush honeysuckle (*Lonicera sp*) and wild blackberry (*Rubus sp.*) are important mid-season (July) alternative hosts for SWD, and may significantly contribute to later season infestation of berry crops. Honeysuckle, wild blackberry, several species of dogwood (*Cornus sp.*), are important mid to late season hosts. Important late season hosts include American pokeweed (*Phytolacca americana*) and dogwood. Although black cap raspberry (*Rubus occidentalis*) and honeysuckle produced some fruit in June, we did not rear out any SWD. During the 2014 we repeated our assessment of non-crop plants as reproductive hosts for SWD. We confirmed that wild blackberry, *Rubus* species, and bush honeysuckle, *Lonicera* species, are important mid to late season hosts and may contribute to infestation risk of berry crops, especially late maturing blueberry, fall raspberry and day-neutral strawberry.

Objective 3: *Evaluate the efficacy of insecticides for control of SWD in small fruit crops.*

During 2013 and 2014 we compared the efficacy of different insecticides and insecticide programs in several different berry crops. We conducted a series of experiments to evaluate the efficacy of adding a small amount of sucrose (sugar) to insecticides as feeding stimulants to increase ingestion of insecticides and toxicity. We found for certain insecticides such as the neonicotinoid acetamiprid (Assail) and the spinosyns Delegate and entrust that sugar increased mortality of SWD. In another field trial with fall raspberries, we compared the efficacy of a currently unregistered insecticide cyazapyr at different rates verses a grower standard of Delegate, applied once per week over about a 4 week period. Cyazapyr (especially the higher rates) appeared to work as well or better than Delegate in this trial in controlling infestations. Cyazapyr also appeared to provide some level of protection for at least two weeks after treatments were stopped while infestation of fruit from Delegate-treated plots were not distinguishable from untreated control plots after one week. In 2014 we focused on examining seasonal insecticide programs for fall raspberry, comparing a standard or conventional rotational program (spinosyn, neonicotinoid, and pyrethroid), a reduced risk program using materials currently labeled for use in NY (spinosyn and neonicotinoid), and a program including a soon to be registered insecticide (cyazapyr = Exeril) that offers a novel mode of action (diamide) for controlling SWD that is also relatively benign for pollinators (diamide, spinosyn, pyrethroid). All of these programs resulted in significantly less fruit infestation by SWD than the untreated control. We conducted a second insecticide efficacy trial with fall raspberries examining the potential of increasing the residual activity of a reduced risk insecticide labeled for SWD (Delegate, a spinosyn) by adding the adjuvant Nu-Film (Miller Chemical and Fertilizer Corp). We found fruit that was field treated with Delegate plus Nu-Film During caused more mortality to adult SWD in lab bioassays compared to fruit treated with just Delegate. The combination of Delegate and Nufilm also resulted in less infestation in the field (that included a rain event) than Delegate alone.

Objective 4: *Evaluate landscape risk factors associated with SWD.*

This objective is concerned with understanding the role of surrounding habitat (landscape factors) in contributing to infestation risk. Thus, objective 4 corresponds well with objective 2 to assess wild plant species as reproductive hosts. We conducted an additional experiment to address objective 4. Specifically, we were interested in directly measuring the extent to which SWD moves from wild hosts in the surrounding habitat to susceptible fruit and vice versa. To quantify movement of adult SWD between a berry crop and surrounding habitat we used a bi-directional passive malaise trap placed between a blueberry field and an adjacent wood lot that included mid and late season hosts such as honeysuckle, blackberry, dogwood, pokeweed, and buckthorn. Most of the captured SWD appeared to be moving from the surrounding habitat to the crop, although this tended to occur later in the season after most of the berry crop was already harvested. Thus, although evidence exists that SWD moves from the woods to crop plantings, the impact on infestation risk will critically depend on timing and we need more information to fully evaluate this question.

Goals and Outcomes Achieved

The performance goals of this project were to describe seasonal phenology of SWD adults in different crops and potential wild hosts and determine the relationship with fruit infestations by larvae in central NY, to assess effectiveness of different lures for monitoring, identify potential risk factors associated with landscape characteristics, and determine optimal use of insecticides for cost effective control. During the project we made progress on achieving all these goals (summarized below). We reported on this progress through talks at winter extension meetings, webinars, workshops, summer twilight meetings, extension publications and research publications (summarized below).

Achievements:

1. Results from monitoring traps and fruit infestation in crops and wild hosts indicate that SWD activity in NY begins in late June to mid-July and tends to peak, in terms of fruit infestation in August. Hence, berry crops maturing before late July (e.g. June-bearing strawberry, summer raspberry, early-maturing blueberry varieties) mostly escape significant infestations while berry crops that mature from late July through September (e.g. fall raspberry, later-maturing blueberry varieties, elderberries, day-neutral strawberries) are very vulnerable.
2. Insecticide trials have shown that a number of products can provide partial to excellent control of SWD in some situations. Some of these products are considered reduced risk, such as Delegate (spinosyn), Entrust (spinosyn), Assail (acetamiprid), and Exirel (cyantraniliprole). We found that for some of these products, adding a small amount of sugar increases efficacy (Assail, Entrust, and Delegate).
3. Fermenting bait based on water, sugar, yeast, and whole-wheat flour placed in a separate container within a cup trap with an apple cider drowning solution captures more adult SWD, earlier in the season than other lures tested. Moreover, with regular monitoring and correct identification of adult SWD, traps with fermenting bait appear to provide reasonable warning of imminent fruit infestation and therefore need to be insecticide treatments. However, this approach may be impractical for most growers because of the difficulty in correctly identifying SWD since the lure and trap capture many different insect species, including species that resemble SWD.
4. Bush honeysuckle and wild blackberry become heavily infested with SWD in mid-summer at about the same time we find infestations in commercial fields. It's still unclear, however, to what extent SWD that successfully develops in these wild hosts colonize berry crops nor whether it would be beneficial to remove these plants from proximity to crops. This is a goal of future research.

Performance measures:

1. We developed and held an in-depth workshop on monitoring and identification of SWD and other Drosophila as part of a training program for regional monitors (mostly personnel working with Cornell Cooperative Extension) in preparation for monitoring SWD for the 2014 field season. The workshop was held in Geneva, NY on 15 May 2014 and was attended by 14 monitors. Training including an overview of the biology and background of SWD and other Drosophila species, information on morphological traits used to distinguish among different species with particular emphasis on characters important in distinguishing SWD males and females from other species, and information on trapping techniques and techniques for processing samples. This was a hands-on workshop that allowed attendees to examine different species of Drosophila using dissecting microscopes with expert trainers proving assistance.
2. We co-organized and participated in a regional meeting of researchers, extension educators, growers, other industry representatives, and government regulators on 16 September 2014 in Highland, NY to review the 2014 field season, results of ongoing research, and to update and modify research, extension, and education priorities for SWD. There were over 30 participants from most states in the Northeast US and eastern Canada. Loeb and postdoc Dr. Anna Wallingford presented talks at the meeting.
3. We co-organized and participated in three all day workshops during the winter of 2014-2015 to share latest research results with growers in NY. The meetings included several hands-on activities, including identification and monitoring of adult SWD, monitoring for larvae in fruit, and insecticide application techniques. Results from this project were included in these workshops. We also provided a resource guide to participants that summarized content from talks and demonstrations. Information from the workshops, including most of the content in the resource guide, is available online on the New York Berry Growers web site at http://www.hort.cornell.edu/grower/nybga/swd/index.html.
4. We updated the Cornell Pest Management Guidelines for Berry Crops annually and incorporated new information generated from this and other projects.
5. The following talks were given on various aspects of the biology and management of SWD in 2013-2015 that include information generated from this project.

Bridgeton, NJ. 30 October 2013. SWD overwintering biology and alternative hosts. 0.25 hours talk as part of the Spotted Wing Drosophila IPM Working Group meeting held in Geneva, NY. Approximately 40 researchers, extension educators, growers, industry leaders, students and regulators present in meeting room and 10 attending remotely through webex. Contact hours = 12.5

Stephentown, NY. 10 September 2013. 3 hour field meeting on biology and management of spotted wing drosophila. On farm visits in eastern NY with approximately 15 growers and extension educators in attendance. Contact hours = 45

Geneva, NY. 1 August 2013. 0.33 hour talk at NYSAES 2013 Fruit Open House. Title of talk: Biology and management of spotted wing drosophila, a major new pest of fruit crops. Co-authors Steve Hesler and Johanna Elsensohn. GL presented. Approximately 80 growers, extension educators, and industry representatives in attendance. Contact hours = 26

Trumansburg, NY. 18 June 2013. Twilight meeting at Silver Queen Farm to discuss current situation with spotted wing drosophila and berry crops. Two hour session. Approximately 20 growers present for meeting that involved demonstrations, show and tell and question and answer session. Sponsored by CCE in southern Tier Kat. Contact hours = 40

Hamden, NY. 11 April 2013. Insects and mites: identification and management. 1.33 hour talk discussion on pests of blueberries with emphasis on invasive species. Approximately 60 growers, home gardeners, and extension educators in audience. Contact hours = 80.

Syracuse, NY. 22 January 2013. Spotted wing drosophila in NY: where have we been and where are we going. 0.33 hour talk as part of symposium on spotted wing drosophila at the New York Fruit and Vegetable Expo held in Syracuse, NY. Approximately 150 growers, industry reps, and extension educators in the audience. Contact hours = 49.5.

Riverhead, NY. 11 January 2013. Risks to grapes from new invasive insects. 0.75 hour talk as part of Long Island Agriculture Forum Viticulture session. Approximately 40 people in attendance. Contact hours = 30.

Syracuse, NY. 17 December 2014. Insecticide efficacy, sugar synergists. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Syracuse, NY on 17 December 2014. I spoke for 15 minutes. Approximately 40 growers, extension educators, and industry representatives in audience. Contact hours = 10.

Syracuse, NY. 17 December 2014. Trap content processing and identifying SWD adults from trap contents. Presentation and hands on experiential learning was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Syracuse, NY on 17 December 2014. Anna Wallingford (postdoc in Loeb Program), who developed this learning module, spoke for 10 minutes and then Anna and others from Loeb Lab led a hands on exercise with attendees focused on adult SWD identification using prepared samples, dissecting scopes and hand lenses for 25 minutes. Approximately 40 growers, extension educators, and industry representatives in audience and participated. Contact hours = 23.3

Syracuse, NY. 17 December 2014. Advances in monitoring and role in management decisions. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Syracuse, NY on 17 December 2014. I spoke for 15 minutes. Approximately 40 growers, extension educators, and industry representatives in audience. Contact hours = 10.

Syracuse, NY. 17 December 2014. Wild hosts and SWD seasonal dynamics. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Syracuse, NY on 17 December 2014. I spoke for 15 minutes. Approximately 40 growers, extension educators, and industry representatives in audience. Contact hours = 10.

Syracuse, NY. 17 December 2014. SWD life cycle, overwintering, and cold tolerance. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Syracuse, NY on 17 December 2014. Anna Wallingford (postdoc in Loeb Program) spoke for 15 minutes. Approximately 40 growers, extension educators, and industry representatives in audience. Contact hours = 10.

Grand Rapids, MI. 9 December 2014. Chemical control of spotted wing drosophila for raspberries in high tunnels and the field. Invited presentation at the Great Lakes Expo as part of the Berries session. Spoke for 25 minutes. Approximately 75 growers, extension educators, and industry representatives in audience. Contact hours = 31.2

Highland, NY. 16 September 2014. SWD research objectives and progress in the Loeb Program. 0.33 hours talk as part of the Spotted Wing Drosophila IPM Working Group meeting held in Highland, NY. Approximately 30 researchers, extension educators, growers, industry leaders, students and regulators present in meeting room. Contact hours = 9.9

Stephentown, NY. 3 hour field meeting on biology and management of spotted wing drosophila with a focus on results of a netting exclusion experiment with blueberries and test of a fixed sprayer system for raspberries. On farm visit in eastern NY with approximately 20 growers

and extension educators in attendance. Contact hours = 60

Geneva, NY. 15 May 2014. Drosophila monitoring and identification for pest management practitioners. Workshop for Cornell Cooperative Extension personnel involved with grower education on *Drosophila suzukii* monitoring and management. There were 11 participants who received hands on training during the four-hour workshop. Contact hours = 33

Geneva, NY. 3 February 2014. SWD overwintering, early-season monitoring and use of wild host plants. 45 minute web x presentation hosted by Pam Fisher with Ontario Ministry of Agriculture and Food. There were approximately 20 researchers and extension educators participating, mainly from Canada. Contact hours = 15.

Hershey, PA. 27 January 2014. Spotted wing drosophila biology and management. 30 minute talk at the annual meeting of the National Raspberry and Blackberry Association. Audience included about 75 growers, industry representatives and extension educators. Contact hours = 37.5.

Hershey, PA. 27 January 2014. Understanding insecticides and how they work in the age of SWD. 30 minute talk at the annual meeting of the National Raspberry and Blackberry Association. Audience included about 75 growers, industry representatives and extension educators. Contact hours = 37.5

Syracuse, NY. 23 January 2014. Enhancing insecticide efficacy with phagostimulants. 30 minute talk as part of the spotted wing drosophila symposium held at the Empire State 2014 Producers Expo. G. Loeb presented with co-authors Steve Hesler, and Johanna Elsensohn. Audience included about 100 growers, extension educators and industry representative. Contact hours = 50.

Syracuse, NY. 23 January 2014. Assessment of lures for monitoring adult SWD. 30 minute talk as part of the spotted wing drosophila symposium held at the Empire State 2014 Producers Expo. G. Loeb presented with co-authors Steve Hesler, Johanna Elsensohn, and Ash Sial. Audience included about 100 growers, extension educators and industry representative. Contact hours = 50.

Geneva, NY. 15 January 2014. Overview of ongoing research investigating SWD biology and management. 1 hour webinar on invasive pests of small fruit and vegetable crops hosted by PSU and Cornell as part of a series of webinars on vegetables and small fruit crops. There were 38 participants (growers, extension educators, master gardeners) on the webinar. Go to https://meeting.psu.edu/p5xe3m3grk8/?launcher=false&fcsContent=true&pbMode=normal to hear full webinar. Contact hours = 38.

Batavia, NY. 4 March 2015. Biological control primer: hummingbirds, parasitoids, microbe entomopathogens and commercially available formulations studies. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Batavia, NY on 4 March 2015. I spoke for 15 minutes. Approximately 50 growers, extension educators, and industry representatives in audience. Contact hours = 12.5.

Batavia, NY. 4 March 2015. Sprayer configurations and using water sensitive cards to assess spray droplet distribution and uniformity. Hands on experiential learning module developed by Steve Hesler (Research Support Specialist in Loeb Program) and Dr. Andrew Landers (Dept Entomology, Cornell University) consisting of displays and demonstrations of sprayers, spray coverage, nozzles, etc. over a 30 minute period. Approximately 50 growers, extension educators, and industry representatives participated. Contact hours = 25.

Batavia, NY. 4 March 2015. Insecticide efficacy, sugar synergists. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Batavia, NY on 4 March 2015. I spoke for 15 minutes. Approximately 50 growers, extension educators, and industry representatives in audience. Contact hours = 12.5.

Batavia, NY. 4 March 2015. Trap content processing and identifying SWD adults from trap contents. Presentation and hands on experiential learning was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Batavia, NY on 4 March 2015. Anna Wallingford (postdoc in Loeb Program), who developed this learning module, spoke for 10 minutes and then Anna and others from Loeb Lab led a hands on exercise with attendees focused on adult SWD identification using prepared samples, dissecting scopes and hand lenses for 25 minutes. Approximately 50 growers, extension educators, and industry representatives in audience and participated. Contact hours = 20.8.

Batavia, NY. 4 March 2015. Advances in monitoring and role in management decisions. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Batavia, NY on 4 March 2015. I spoke for 15 minutes. Approximately 50 growers, extension educators, and industry representatives in audience. Contact hours = 12.5

Batavia, NY. 4 March 2015. Wild hosts and SWD seasonal dynamics. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Batavia, NY on 4 March 2015. I spoke for 15 minutes. Approximately 50 growers, extension educators, and industry representatives in audience. Contact hours = 12.5

Batavia, NY. 4 March 2015. SWD life cycle, overwintering, and cold tolerance. Presentation was part of the Spotted Wing Drosophila Winter Regional Workshop sponsored by NYS BGA and Cornell University and held in Batavia, NY on 4 March 2015. Anna Wallingford (postdoc in Loeb Program) spoke for 15 minutes. Approximately 50 growers, extension educators, and industry representatives in audience. Contact hours = 12.5

Niagara Falls, Ontario, Canada. 19 February 2015. Greg Loeb and Anna Wallingford. SWD research updates from the Northeast working group. Invited speaker as part of the spotted wing drosophila session at the 2015 Ontario Fruit and Vegetable Conference held in Niagara Falls, Ontario. Presented a 30 minute talk to approximately 40 growers and industry representatives. Contact hours = 20.

Niagara Falls, Ontario, Canada. 19 February 2015. Anna Wallingford, J. Elsensohn, and G. Loeb. What you need to know. Postdoc Anna Wallingford was invited speaker as part of the spotted wing drosophila session at the 2015 Ontario Fruit and Vegetable Conference held in Niagara Falls, Ontario. Presented a 30 minute talk to approximately 40 growers and industry representatives. Contact hours = 20.

Syracuse, NY. 22 January 2015. G. Loeb and D. Riggs. Spotted wing drosophila research update. 25 minute joint presentation at the 2015 Empire State Producers Expo, held January 19-22 in Syracuse, NY. We spoke during the afternoon portion of the day-long berry session. Approximately 75 growers, extension educators and industry representatives in audience. Contact hours = 31.2.

6. The following extension publications were produced that include information generated from this research.

2015 Lee, J, Dreves, A., Isaacs, R., Loeb, G., Thistlewood, H., and Brewer, L. Noncrop host plants of spotted wing drosophila in North America. Fact sheet produced through Oregon State University Extension Service, EM 9113, April 2015. http://www.ipm.msu.edu/uploads/files/SWD/em9113.pdf

2014 Loeb, G. and Hesler, S. 2014. Early detection and management of spotted wing drosophila in raspberry. The Bramble 29 (3): 8-9.

2014 Loeb, G., S. Hesler, J. Elsensohn, and A. Sial. Assessment of lures for monitoring adult swd. New York Berry News, 12 (9): 7-8. Available online at

http://www.fruit.cornell.edu/nybn/newslettpdfs/2014/nybn1305.pdf.

2014 Loeb, G., J. Elsensohn, and S. Hesler. Enhancing insecticide efficacy with phagostimulants. New York Berry News, 12 (9): 14-15. Available online at http://www.fruit.cornell.edu/nybn/newslettpdfs/2014/nybn1305.pdf.

2014 Elsensohn, J. and G. Loeb. Season long evaluation of wild hosts for spotted wing drosophila. New York Berry News, 12 (9): 24-25. Available online at http://www.fruit.cornell.edu/nybn/newslettpdfs/2014/nybn1305.pdf.

2014 Loeb, G., C. Heidenreich, L. McDermott, P. Jentsch, D. Breth, and J. Carroll. Labeled insecticides for control of spotted wing drosophila in New York Berry Crops. Available online through Cornell Fruit, Spotted Wing Drosophila web page at http://www.fruit.cornell.edu/spottedwing/pdfs/swd-insecticides-berries-ny.pdf

2013 Loeb, G., C. Heidenreich, L. McDermott, P. Jentsch, D. Breth, and J. Carroll. Chemical control of SWD in berry crops. New York Berry News, May Issue, pp. 2-5.

2013 Loeb, G. Spotted wing drosophila in New York: Where we are and where we are heading. New York Berry News, January Issue, pp. 11-14.

2013 Loeb, G. Spotted wing drosophila in NY: where we are and where we are heading. Proceedings of the 2013 Empire State Fruit and Vegetable Expo, Syracuse, NY. http://www.hort.cornell.edu/expo/proceedings/2013/Drosophila/Drosophila%20Loeb%20SWD%20in%20NY.pdf

7. The following research publications were produced that include information generated from this project.

2015. Burrack, H.J., Asplen, M., Bahder,L., Collins, J., Drummond, F.A., Guedot, C., Isaacs, R., Johnson, D., Banton, A., Lee, J.C., **Loeb, G**., Rodriguez-Saona, C., Van Timmeren, S., Walsh, D., and McPhie, D.R. Multi-state comparison of attractants for monitoring *Drosophila suzukii* (Diptera: Drosophilidae) in blueberries and caneberries. Environmental Entomology, In Press.

2015. Cowles, R.S, Rodriguez-Saona, C., Holdcraft, R., **Loeb, G.M.,** Elsensohn, J.E., and Hesler, S.P. Sucrose improves insecticide activity against *Drosophila suzukii* (Diptera: Drosophilidae), Journal of Economic Entomology 108: 640-653.

2015. Cha, D.H**.**, Hesler, S.P., Park, S.Y., Adams, T., Zack, R., Rogg, H., **Loeb, G.M**., Landolt, P.J. Simpler is better: fewer nontarget insects trapped with a 4-component synthetic lure verses a chemically comples food-type bait for *Drosophila suzukii*. Entomologia Experimentalis et Applicata 154: 251-260.

2013. Cha, D.H., Hesler, S.P., Cowles, R.S., Vogt, H., **Loeb, G.M**., and Landolt, P.J. 2013. Comparison of a synthetic chemical lure and standard fermented baits for trapping *Drosophila suzukii* (Diptera: Drosophilidae). Environmental Entomology 42: 1052-1060.

Beneficiaries

The 2011 farm gate value of berry crops and stone fruit (peaches and sweet cherries) in NY was approximately $23 million and involves hundreds of growers managing close to 8,000 acres. Grapes may also be vulnerable to SWD under some conditions, and this involves another 30,000 plus acres at a farm gate value of $67 million. These growers are the principal beneficiaries of this project, who have benefited from improved understanding of pest phenology and monitoring methods, identification of crops at greatest risk,

identification of landscape factors associated with greater risk and improved control methods generated through this project. The economic impact of this project is that growers are able to better manage SWD in berry crops and produce more clean fruit that is available for sale over a longer part of the season.

In 2012 we estimated, based on grower surveys, that SWD resulted in a loss of approximately $4.3 M for raspberry and blueberry growers in NY State, which involved an estimated 80% loss in raspberries ($3 M) and 30% loss in blueberries ($1.3 M). In 2015 we estimate that losses in raspberries have been reduced to 20% and 15% in blueberries through better management due, in part, to outcomes of this project. Based on 2012 estimates of crop value, this represents a 65% reduction in losses due to SWD valued at $2.9 M.

Lessons Learned

Our assessment of SWD phenology and crops at risk included grapes. One interesting finding was that we did not find much evidence of direct egg-laying by SWD into the main grape cultivars grown in NY. In other words, we did not rear many SWD out of intact berries. However, when we examined damaged berries caused by various forces (e.g. birds, hornets, hail), we did rear out Drosophilia, including SWD, but more so *D. melanogaster*. Moreover, we have observed an association between the activity of Drosophila and problems with sour rot in some grape cultivars. Since SWD becomes very abundant in the fall, it may play a major role. This is a subject of other research going in the lab in collaboration with Dr. Wayne Wilcox, plant pathologist at Cornell.

In our research on lures and traps for monitoring SWD we gained new insights into what features would be most helpful to growers to make it worth their while to do monitoring at their farms. First, and most important, the lure/trap has to provide sufficient warning of infestation risk for them to implement a management action. Second, it would be helpful if they could rely on male captures only since these are the easiest to discriminate from other species of fruit flies. Third, it would be helpful if they did not need to change the bait every time they checked the traps. And fourth, it would be helpful if the lure and drowning solution was selective to SWD so they did not need to sort through non targets. Research conducted in the 2015 field season began addressing these features.

Our research on what wild hosts are used by SWD for reproduction indicated several things that were somewhat surprising to us. First, wild hosts that ripen fruit in August are the most important in terms of production of SWD. Second, wild hosts that ripen fruit in June to early July, even if the fruit is a good host for SWD, are not utilized by SWD. And third, wild hosts that ripen fruit in later fall, although good SWD hosts, are also not heavily utilized by SWD since the flies are entering reproductive diapause.

Our research on insecticide efficacy revealed a couple of somewhat surprising findings. First, insecticides are much more effective when the operator (or researcher) is careful to harvest ripe fruit on a frequent basis. Allowing a collection of ripe and overripe fruit in the field compromises efficacy. Related to this, once infestation becomes extensive, it is very challenging to get control of SWD since so much of the population is protected within fruit as larvae. Third, developing effective insecticide programs for SWD for crops with extended harvest such as fall raspberries and blueberries, is challenging because of use restrictions such as days to harvest, maximum amount of material and number of applications allowed, impact on beneficiaries, concerns about resistance, and the relatively short period of residual activity, especially during periods of frequent precipitation.

We accomplished most of the goals for this project. One goal we had at the start of the field season was to develop a method to remove fruit from wild hosts near vulnerable berry crops as a way to directly test whether this practice is a viable method to reduce SWD infestation risk. Unfortunately, our chosen method of applying high levels of a plant growth hormone was not successful. The objective to evaluate landscape risk factors associated with SWD infestation included a proposal to use ARC GIS (quantifying percentage of different habitat types at different distances from focal farms and relating to infestation) to assess the role of

landscape factors. However, we decided this was not a useful approach to address this objective for two reasons. First, the resolution of habitat down to plant species is not practical with current maps. And second, the number of sites necessary in such an analysis is not practical within the framework of this grant.

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Project 9

Examining Current Labor Options and the Impact of Labor Policy Reform on Specialty Crop Farms in New York State

Project Summary

New York State is a key production state for various fruits and vegetables, and the top issue among specialty crop producers in New York State is the availability of labor to facilitate the production and harvest of these crops. There were two primary objectives in this project. First, we collected data on current labor management practices across a range of specialty crop producers to shed new light on the impacts of various approaches to sourcing, managing and retaining human resources in New York State. Second, we provided new analysis to better understand the potential impacts of changes in labor policy that would allow an expansion in the number of guest worker visas.

Farmers managing labor intensive specialty crop operations must cope with major risk and uncertainty associated with the perennial challenges of hiring a legally authorized and reliable workforce in an exceptionally challenging, seemingly intransigent immigration policy, regulatory and enforcement environment. To address these ongoing challenges, farmers have experimented with and adopted a variety of practices to manage such labor risk. To date, only anecdotal evidence has informed our understanding of the effectiveness of these alternative human resource management practices. Similarly, over the past decade Congress has entertained, yet failed to pass a range of immigration policy proposals affecting agriculture, from targeted changes such as the AgJobs bill to comprehensive reform legislation. In order to improve the competitiveness of New York fruit and vegetable production systems and improve our understanding of alternatives available to address a high priority issue for labor intensive agricultural operations, this project systematically evaluated various labor risk management options and measured the economic effects of potential immigration policy reforms on specialty crop agriculture and markets in New York State.

Project Approach

Our original proposal included seven activities that were largely centered on two main objectives. The first objective was to collect information from industry stakeholders on their labor management practices and thoughts on how they would adjust to any potential changes in immigration policy in the United States. Results from this activity have been summarized in two documents that have been posted to our department's website. The first, titled "*Labor Issues and Employment Practices on New York Apple Farms*," provides a qualitative assessment of the labor practices that are used on selected apple farms in New York State based on a survey we conducted. The second, titled "*Workforce Issues: Profiles of Specialty Crop Farms in New York State*" presents a series of in-depth interviews with eight specialty crop producers in NYS and focuses on their labor management techniques and their thoughts on how their businesses will evolve over the next decade in light of their experiences sourcing labor.

The purpose of the study was to identify and describe the various strategies and practices followed by New York specialty crop growers to secure and manage a reliable supply of qualified workers. The study was also intended to identify workforce challenges facing specialty crop growers and to explore solutions to those challenges. Case-study results are intended to be helpful to specialty crop growers, policymakers and educators as they participate in agricultural labor policy related conversations at the state and local levels.

This study was intended to describe employment practices and challenges on individual farms. It is not a comprehensive survey of specialty crop growers and as such cannot be used to describe the entire industry. It describes only those farm businesses profiled here. The case study approach is valuable, however, because it allows the opportunity to examine workforce issues at a level of detail that would not be possible with a conventional survey.

Eight New York specialty crop farms were selected for a 60 to 90 minute recorded interview. The farms selected were large, progressive farms utilizing modern human resource management practices. The individuals interviewed from each farm were asked a series of questions relating to four primary topic areas: a description of the farm operation and workforce, recruiting and hiring practices, staffing challenges, and labor concerns and alternatives.

Most of the farm employers interviewed reported that labor is now much tighter than it was five to ten years ago. Much of the pressure on labor supplies has to do with the number of undocumented Hispanic workers that have entered the agricultural workforce over the last decade and recent pressure from immigration enforcement officials. As a result of tighter labor supplies, many farm employers are using the H-2A program and/or seeking other labor alternatives. The available supply of labor is also smaller than it was decades ago, as both Americans and children of immigrants are less willing to do agricultural work, and those that are willing are demanding higher wages. Farm employers noted various ways in which they have come to cope with tight labor supplies, including growing less labor intensive produce, mechanizing, or relying on H-2A. Most employers interviewed believe that the tightness in labor supplies for agriculture is likely to continue for years to come, and a critical element for relief is immigration reform.

The second objective centered on a quantitative analysis of how potential changes in immigration policy, notably how an increase in the number of guest worker visas, would affect economic welfare for specialty crop growers in New York State. The research employed a multi-market model to simulate the likely effects of an expanded guest worker program for producers of horticultural crops, and for the factors of production that support these industries. We extended the model introduced in Becker (1983) and applied it in a series of simulation experiments to explore the conditions under which an expanded guest worker program may benefit specialty crop producers.

Two key findings emerged from the simulation results. First, an expansion in the agricultural labor supply does lead to disproportionally larger benefits to producers of horticultural crops and to the firms that supply inputs to the horticultural industry. Second, of the three input markets included in the analysis, the labor market is most affected by a change in the supply of agricultural labor. Yet, relative to the baseline results, the markets for the land input and the other input are most affected once substitution is allowed between crops or between inputs. Overall, the simulated effects in the horticultural crop market and in the labor market were robust across the various models. This research presents a careful analysis of how an expansion in the number of guest workers may affect producers of horticultural crop markets, and the suppliers of inputs to these crops. The debate on immigration reform in the United States involves many stakeholders beyond agriculture, and there certainly exist larger political and economic issues in these negotiations. However, it appears that there may also be valid reasons for competition among pressure groups within agriculture for political support, and that increasing the agricultural labor supply is an issue that does not draw strong support from all agricultural industries. Although the lack of consensus within agriculture on this issue is not the primary impediment on immigration reform in the United States, it may be one of the contributing factors to the absence of any legislative action that would introduce changes to the guest worker program.

In our original proposal we included four letters of support from industry stakeholders. Although none of the letter writers were official project partners, we did recruit two of them to participate in our case study work, and they helped us identify six other individuals to interview for additional case studies. The time and effort that the eight individuals spent with us was significant, and we acknowledge their contribution in the report that summarizes the case studies.

Goals and Outcomes Achieved

In our original proposal we included the seven activities shown below. A revised project that was approved by NYSDAM eliminated Task 7 as the Becker Forum in 2015 did not focus on labor management

and labor policy issues. We have completed work that successfully addressed the other six tasks outlined below.

Task 1: *Develop tools to collect information on current labor management practices*
Task 2: *Data collection, data organization, evaluate descriptions of various labor management practices/strategies used by specialty crop producers in NYS*
Task 3: *Document findings from data describing current labor management practices*
Task 4: *Work with industry stakeholders to highlight potential changes in labor policy, including changes in H-2A*
Task 5: *Develop a framework to assess the economic effects of potential labor policy changes in agricultural markets (horticultural markets and other non-horticultural markets)*
Task 6: *Document research findings from policy analysis; consider the interaction effects of various alternative scenarios with current labor management practices*
Task 7: *Disseminate project findings as part of Becker Forum 2015*

The outcome measures for project centered on helping New York's fruit and vegetable growers obtain a sufficient number of productive agricultural workers on a timely basis to assist with growing and harvesting operations for fruits and vegetables. Therefore, this is a long term outcome. Yet our work has helped towards this outcome in the shorter run by supplying new information about labor practices, labor management techniques currently used by NYS farms, and the likely effects of an expanded guest worker program. Anecdotal evidence suggests that fruit and vegetable growers in New York State have experienced labor shortages leading to lost crop yields and reduced quality of fresh fruits and vegetables in recent years. Reasons for these occasional shortages include delays and uncertainty with the H-2A program as well as immigration enforcement activities that detain or discourage potential workers from seeking employment in New York State. Our results provide substantially more information about the labor recruiting challenges that farm employers face, the pressure on management to overcome those challenges, alternative labor sources and management practices and potential policy solutions.

Our accomplishments over the course of this project line up very well with our original goals and tasks outlined in the original proposal. In fact, we think that we have delivered more than we promised as we were able to conduct a state-wide survey on labor practices plus the in-depth interviews on specific labor management techniques for eight operations.

In addition, we were able to complete many of the expected measurable outcomes that were listed in the project proposal that involved presentations to stakeholders in New York State and elsewhere. Findings were presented results at the following events:

- Rickard, Bradley. 2013. "The political economy of guest worker programs in agriculture." Presented at the FDRS Annual Meeting. Chicago, IL. October 7, 2013. 35 stakeholders.
- Rickard, Bradley. "Situation and Outlook Report for Fruits and Vegetables." Presented at the AEM Agricultural Outlook Conference. Ithaca, NY. December 18, 2012. 25 stakeholders.

- Smith, M., T. Maloney, and B. Rickard. "An overview of labor management options and the likely effects of labor policy reform in the horticultural industry." Presented at the New York Produce Show and Conference. New York, NY. December 5, 2012. 35 stakeholders.
- Rickard, Bradley. "The Competitiveness Situation for New York State's Processing Vegetable Industry." Presented at the Processing Vegetable Crops Session as part of the Fruit and Vegetable Expo, Syracuse, NY. January 24, 2012. 50 stakeholders.
- Rickard, Bradley. "An Update on Horticultural Markets and Policies in NYS." Presented to Governor Cuomo's Staff, A Meeting Organized by CALS. Ithaca, NY. July 19, 2011. 15 stakeholders.

The survey and case study work as part of our project did not collect data, per se, but collected qualitative information that provides meaningful information to growers and policy makers about labor practices and labor management options used in the NYS. The simulation work that was published in *Food Policy* also does not collect data, per se, but does use existing data to help project the likely economic effects to specialty crop growers in the event of an expansion in the number of guest worker visas.

Beneficiaries

Our findings from the survey work, the case studies, and the simulation results constitute a valuable package of information with which growers can use to improve decisions about the adoption of the various labor management strategies. Although other researchers have investigated issues related to farm labor supply and labor management practices, previous work has not fully addressed labor market conditions in New York State. The list of beneficiaries includes a wide range of stakeholders involved in fruit and vegetable production in New York State including growers, packers, marketers, and policy makers.

Our results are also valuable to a similar set of stakeholders in specialty crop operations in other Northeast states. Our findings have been widely disseminated to participants at various Cornell Cooperative Extension events between 2012 and 2015. Below we provide a link to a promotional write-up for a presentation made at the 2012 NY Produce Show and Conference in NYC that attracted a very large and diverse audience. This write-up from that presentation was viewed by more than 1,000 individuals that subscribe to the *Perishable Pundit*.

Prevor, J. "Immigration, One of the Hottest Post-Election Issues, Will Be Brought To the Floor of the New York Produce Show and Conference." Featured Interview on the *Perishable Pundit*. October 2012. Available at: http://www.perishablepundit.com/index.php?article=2795

For our project, we feel that the beneficiaries are not necessarily looking for quantitative data but are looking for qualitative information that will help them better understand the common labor practices and the various options farms are using to source labor for their operations. We do provide quantitative details that describe average benchmarks for specific labor activities in NYS in each of the three publications related to this project, but these data are mostly provided to support the larger package of information.

For this type of project it is difficult to accurately quantify the beneficiaries of the implementation of this research or the potential economic impact of the work given the long term nature of the issue and the problem we seek to study. Overall, our work says more about the economics of various counter-factual scenarios with reduced or alternative labor pools. However, we feel that our research makes two non-trivial contributions that have meaningful economic impact to horticultural producers in NYS. First, we were able to communicate the economic importance of a reliable labor supply for NYS fruit farms and illustrate the economic costs associated with a reduction in the labor supply. Second, we outline a variety of ways that NYS producers are managing their workforce with a non-traditional labor supply. If other growers adopt

similar pools of alternative labor supply it could generate additional economic activity in the NYS horticultural community.

Lessons Learned

The research team learned a significant amount about labor management and labor use on NYS specialty crop farms. We think the most profound and interesting information resulted from the in-depth interviews we conducted with individuals from farm operations. Below we summarize some of the key lessons we learned from those growers in five different categories: H-2A visas, thoughts on immigration reform, alternative labor pools, mechanization, and competition for workers.

H-2A Visas

The H-2A Program, administered by the United States Citizenship and Immigration Services (USCIS), enables the admission of foreign nationals into the United States to complete temporary agricultural jobs. In order for farm employers to request temporary agricultural workers, they must go through a lengthy and costly process involving considerable paperwork. One recurring criticism among the farmers using H-2A was that I-129 forms are reviewed by multiple agencies, and each agency has the authority to cite discrepancies based on their interpretation, which can result in delays in getting the workers to the farm. The discrepancies with which agencies take issue often vary from year to year. Such inconsistencies place an unnecessary administrative burden on farmers.

Farmers also note how the program's inflexible nature makes it difficult for them to staff their farms for the entire growing season. H-2A workers are unable to work for multiple farms, but given the many uncertainties in agricultural production arising from weather events, market conditions and other external factors, labor needs vary throughout the seasons depending on the operation. There are also times when farms may experience labor surpluses or shortages (depending on their crop yield) because H-2A workers are unable to work for a neighboring farm that may need labor, but farms are still required to pay 75% of the advertised salary under H-2A's "three-fourths guarantee" rule (http://www.dol.gov/whd/regs/compliance/whdfs26.pdf).

Nationwide, the H-2A program is responsible for providing less than 4% of hired agricultural workers, and the seasonality of the program hinders the ability of year round producers to utilize the program (http://www.agworkforcecoalition.org/wp-content/uploads/2014/06/05-AWC-Talking-Points.pdf). Farmers interviewed that do not use H-2A said they didn't use the program because it was too costly, difficult to manage, and inflexible for their operation. All agree that a more streamlined process would make the H-2A Program much more efficient and beneficial for all parties. Growers understand and accept that oversight and regulation is necessary, but not to the extent currently being employed.

Thoughts on Immigration Reform

The agricultural industry nationally has a focused immigration policy agenda. The Agricultural Workforce Coalition (AWC), a group of agricultural producer organizations from across the United States, represents agriculture's interests on the immigration issue. The stated position of the AWC is that agricultural operations must have access to a stable and skilled workforce. In order to achieve that goal, the coalition is calling for two major policy changes. First, a program is needed that provides adjustment in immigration status for current undocumented workers employed in agriculture. Second, the coalition is calling for a modern guest worker visa program that will address current agricultural workforce needs and include the dairy industry. Presumably a new guest worker program would replace the current H-2A program.

The general sentiment among farmers interviewed for this study is that they are not optimistic about the near-term possibility of immigration reform, nor do they believe the government is willing or able to

address the many issues with the H-2A program or create a new, adequate guest worker program. However, most of the farm owners interviewed stand ready to engage in the political process relating to immigration reform if and when the future opportunity arises.

Alternative Labor Pools

Given that most of the farms in this study have experienced tight labor supplies to one extent or another, most have explored alternative labor pools. These include Puerto Rican workers, refugees and J-1 workers. However, growers noted issues with each of these alternative labor pools that have prevented their widespread use and adoption. For example, refugees are largely urban-based, but a more rural model is needed, and J-1 student workers aren't allowed to directly engage in agricultural labor.

The growers interviewed also acknowledged that local workers increasingly do not want to do agricultural work. Yet, some of those interviewed continue their attempts to recruit and hire local workers as much as possible to alleviate the risk of hiring undocumented workers. Even though many of the farms interviewed do draw from these alternative labor pools, undocumented Hispanic workers continue to provide a substantial amount of labor for agriculture. In the absence of Hispanic workers, many employers have begun to use the H-2A program. Although there are alternatives to both these labor pools as previously mentioned, none of the alternative labor pools to date provide the opportunity to hire large numbers of agricultural workers. So, while Puerto Rican workers, refugees, and J-1 workers will continue to provide some relief for a handful of farm employers, they do not represent a wholesale solution for labor intensive agriculture.

Mechanization

All of the farm owners interviewed for this study reported increased interest in mechanization as a way to alleviate some of their labor challenges. Agriculture has been mechanizing for decades as technological improvements become more readily available and affordable. As the pool of available workers shrinks, the adoption of new equipment and facilities increases. Most of those interviewed reported making major capital investments in new, modern labor saving equipment. Others reported fabricating labor saving equipment in their farm shop. All of these efforts have the goal of either reducing the amount of workers hired or substantially increasing productivity with the same number of workers.

Some farms also reported shifting production from hand harvested crops to mechanized row crops. Mechanization is usually highly capital intensive, however, so farm employers are constantly examining the trade-off between labor costs and capital investments in labor saving equipment. The trend toward mechanization of labor-intensive agricultural jobs is likely to continue, if not accelerate.

Competition for Workers

A number of farm employers reported competition for workers between farms. One of the most dramatic examples was that vegetable growers had difficulty getting fall crops harvested because apple harvest occurred at the same time and some workers shift to picking apples because they can make more money (picking apples) than harvesting vegetables. Another grower noted workers are drawn to larger farms that are able to provide housing and benefits, and smaller operations have a difficult time offering competitive wages and benefits. One grower interviewed also voiced concern that New York State's decision to increase the minimum wage to $15/hour for fast-food chain restaurant employees could draw more people away from the agricultural sector, placing additional strain on farm employers' ability to secure adequate labor supplies. Competition for workers is likely to continue and that will, in turn, put upward pressure on wages and benefits for farm workers.

The results from the survey work that conducted the in-depth case studies surprised us in a few ways. Each of eight selected specialty crop growers was asked to describe their farm operation,

characteristics of their workforce, and the workforce challenges they face. The interviews addressed four main topics: Description of Farm Operation and Current Workforce, Recruiting and Hiring Practices, Staffing Challenges, and Labor Concerns and Exploring Workforce Alternatives.

The interview discussions revealed a number of issues that significantly influenced farm management decisions. Immigration reform is a major concern for the growers interviewed, although most were not optimistic that reform would come soon. Most of the agricultural employers interviewed feel that workable immigration reform is essential to the future of U.S. agriculture. Many reported that fewer qualified agricultural workers have been available over the last five years. As a result, there is greater competition for workers among farmers, as well as nonfarm employers.

In an attempt to expand the pool of qualified workers, some farmers are looking at alternative labor pools such as refugees, Puerto Rican workers and workers with J-1 visas. Tighter labor supplies have also resulted in increased use of the H-2A program, especially by owners of larger farms. All farm employers interviewed also discussed efforts to mechanize the most labor intensive jobs on the farm. Some reported substantial capital investments in new labor saving equipment and facilities.

In the end, we were able to complete all of our tasks and goals with this project (with the exception of the outreach task that was out of our control). Looking back, we may have spent more time earlier on thinking about the survey design and pilot-testing it with a few more stakeholders to fine tune things better before we began our data (i.e. information) collection. Spending more time up front on this activity may have allowed us to collect more information from a greater number of operations. In addition, it may have allowed us to better harmonize the information from the surveys with the parameters used in the simulation model exercise.

Additional Information

Below are the titles and full citations for the three publications that are the result of this project.

1. Rickard, B.J. 2015. On the political economy of guest worker programs in agriculture. *Food Policy* 52(April): 1–8. http://ac.els-cdn.com/S030691921500007X/1-s2.0-S030691921500007X-main.pdf?_tid=e18af2a4-66c7-11e5-ac00-00000aacb362&acdnat=1443544617_b458082f36012ad078a1dfab8f2827dc
2. Baker, P., A. De Marree, S.-T. Ho, T. Maloney, and B. Rickard. 2015. Labor Issues and Employment Practices on New York Apple Farms. *AEM Extension Bulletin No. 2015-02*. http://publications.dyson.cornell.edu/outreach/extensionpdf/2015/Cornell-Dyson-eb1502.pdf
3. Maloney, T., M. Smith, R. Saputo, and B. Rickard. 2015. Workforce Issues: Profiles of Specialty Crop Farms in New York State. *AEM Extension Bulletin No. 2015-11*. http://publications.dyson.cornell.edu/outreach/extensionpdf/2015/Cornell-Dyson-eb1511.pdf

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Project 10
Developing Weed Suppressive Turf for Organic Landscape Management

Project Summary

In New York State (NYS), there is a growing demand for lawns and playing fields that restricts the use of pesticides. In the past two years, the State passed the *Child Safe Playing Fields Law* banning the use of conventional pesticides on all public and private school grounds and daycare centers. Additionally, the NYS Department of Environmental Conservation (DEC) has expanded their *Be Green Organic Yards* program to include more participants since its introduction two years ago. With few chemical control options available, superintendents, groundskeepers, and lawn care providers are concerned with facing more weeds in their landscapes each year as they adhere to pesticide-free land management. We established new mixtures of grasses comprised of fine fescue and Kentucky bluegrass varieties that can suppress weeds while maintaining a healthy, dense stand of turf. The aim of this project was to provide schools, daycare centers, and organic lawn care providers the benefit of adopting improved weed management practices that do not rely on conventional herbicides. We expect that the development of weed suppressive grass mixtures will benefit the NYS turf and landscapes industry, as well as school and community groups that are concerned with the prevalent use of pesticides in their communities.

NYS continues to pass legislation restricting the use of pesticides on turf and landscapes. The Neighbor Notification Law of 2000 and the Child Safe Playing Fields Law of 2010 have created high demand for alternative weed management methods that do not rely on conventional herbicides. The Cornell Turfgrass Program continues to provide assistance to the NYS stakeholders affected by the legislative restrictions, but the recent school grounds pesticide restriction law allows few alternatives for turf management. Without funding resources for development of pesticide-free turf management methods, the school districts are struggling to maintain playable fields and unobstructed fence lines.

The research experiment we conducted addresses the challenges emerging from the new NYS legislation banning pesticides on school grounds and daycare centers. The project responds also to the growing demand in NYS for reduced herbicide use on lawns and playing fields. The objectives of the project were:

1) Identify turfgrass species that show weed suppressive traits;
2) Examine the ability of the weed-suppressive turfgrasses to establish in mixtures of Kentucky Bluegrass (the standard cool season turfgrass and sod farm cultivar);
3) Evaluate the appropriateness of the new turfgrass mixtures as commercial sod cultivars and direct seeding mixtures on school grounds and organically managed turf landscapes.

Project Approach

Objective 1*: Identify turfgrass species that show weed suppressive traits.*

We addressed the first objective by conducting greenhouse experiments that measured turf quality traits of several fine fescue and Kentucky bluegrass varieties (Fig. 1). The mesocosms containing the fine fescue-only and fine fescue-Kentucky bluegrass mixtures suppressed weed establishment. The greenhouse trial showed that the turfgrasses were able to form dense stands, with a turf density coverage averaging 99%. However, in a field setting, turfgrass landscapes are highly disturbed when used as playing fields. The Kentucky bluegrass component of the mixtures is important for withstanding traffic from athletic or recreational activities. It is a lateral-spreading grass species that forms rhizomes in the soil aiding in turf recovery from disturbance.

Figure1. Greenhouse study at the Cornell Ithaca campus showing several fine fescue and Kentucky bluegrass varieties. Weeds were suppressed in the fine fescue-only and fine fescue-Kentucky bluegrass mixtures.

Previous research on the fine fescue variety trials conducted by Co-principal Investigator, Dr. Frank Rossi, indicated that several varieties of fine fescues have weed suppressive traits. We referenced the scientific literature to fact check the mechanisms explaining the high weed suppressive nature of the fine fescues. Several published papers confirmed that many of the fine fescue varieties produce an allelopathic compound that is released from the roots into the soil. The compound, m-tyrosine, is able to inhibit the growth of several weed seedlings when grown in petri plate growth assays. The combined information on the performance of fine fescue varieties under field, greenhouse, and laboratory conditions allowed us to select two varieties of fine fescues and three varieties of Kentucky bluegrasses for the field experiment.

Objective 2*: Examine the ability of the weed-suppressive turfgrasses to establish in mixtures of Kentucky Bluegrass (the standard cool season turfgrass and sod farm cultivar).*

We established 48 plots at the Cornell Turfgrass Research Site comprised of two varieties of fine fescues (*Festuca rubra*) that produces the allelopathic compound (m-tyrosine) and three varieties of Kentucky bluegrass (*Poa pratensis*) that produce rhizomes for better traffic tolerance. The design of the experiment includes a split-plot block consisting of traffic vs. no traffic with six different ratios of FF/KBG mixtures within the traffic treatments (Table 1). Six turf mixes composed of varying proportions of fine fescue (FF) and Kentucky bluegrass (KBG) were seeded and established in fall 2014.

These mixes were labeled ‘1’ through ‘6’ and consisted respectively of (%FF/%KBG) 100/0, 80/20, 60/40, 40/60, 20/80, and 0/100. Eight plots of each mix were seeded and half of them were subjected to light traffic and the other half were not. Traffic was administered using a

rolling drum apparatus developed at Cornell University that simulates light-medium traffic similar to what would be experienced in a residential or commercial turf. Turf quality indices were assessed in the fall of 2014 and included aerial photography, dark green color index, tensile strength of cut sod, weed suppressiveness, and actual ratios of fine fescue to Kentucky bluegrass.

Weed pressure increased significantly with the percentage KBG in the plot. The weed percentages in order were ~2.9%, 5.0%, ~6.4%, 8.8%, 16.9%, and 64%. The percent weed results were log transformed for normality and to determine significance. These results are consistent with the weed suppressiveness attributed to fine fescues, and demonstrate its effectiveness at as little as 20% of the seeded mix.

Table 1. Field experiment to determine the efficacy of weed suppressive fine fescue-Kentucky bluegrass mixtures. Each of the six mixture treatments includes four replicated plots. The entire design is duplicated to create a split-plot design of traffic vs. no-traffic blocks.

Fine fescue and Kentucky bluegrass mixes	**Pounds/1,000 sq ft.**
100% FF	5.7 FF/ 0 KBG
80%FF/20%KBG	4.56 FF/ 0.41 KBG
60%FF/40%KBG	3.42 FF/ 0.82 KBG
40%FF/60%KBG	2.28 FF/ 1.22 KBG
20%FF/80%KBG	1.14 FF/ 1.63 KBG
100%KBG	0 FF/ 2.04 KBG

Objective 3*: Evaluate the appropriateness of the new turfgrass mixtures as commercial sod cultivars and direct seeding mixtures on school grounds and organically managed turf landscapes.*

Commercial sod production requires the turfgrass mixture to hold together for cutting and transportation to the client. Tensile strength is a measurement used to determine how well the turfgass can withstand the stresses of cutting, rolling, and transportation. Tensile strength varied significantly with the percent KBG in the mix. The tensile strengths of the mixes were 84 lbs., 78 lbs., 90 lbs., 72 lbs., 71 lbs., and 41 lbs. from Mix 1 to Mix 6. Mix 6 is the lowest value, again, likely due to the heavy weed pressure. Despite not being a sod forming grass, the FF showed tensile strengths sufficient for sod cutting even in the 100% FF mix (Mix 1).

All mixtures containing FF displayed the desired weed suppression, with greater ratios of FF corresponding to greater weed suppression, when directly seeded. In addition, greater ratios of FF were also associated with greater tensile strengths. Mixes 1, 2, and 3 showed the highest tensile strengths, which indicate strong potential for these mixes as sod. It is important to note that all stands were higher in FF relative to the seeding rate except in Mix 5 (Traffic).

Figure 2. Aerial photo of the weed suppressive turf plots at the Cornell University turf research and extension facility

Given the poor performance in terms of weediness and tensile strength of the higher-KBG mixes, the results of this study indicate that all-FF turf performs well as an organic, weed-suppressive landscape turf. However, the presence of 10-30% (actual rate) KBG does not have any significant negative effect on weed suppression or tensile strength and may provide versatility when one mix is to be applied across a varied landscape. Further study with different varieties and across different landscape conditions may yield more effective combinations for specific applications.

Goals and Outcomes Achieved

We accomplished many goals in this project and addressed all three objectives successfully. We identified two commercially available cultivars of fine fescue that produce the allelochemical (m-tyrosine) that inhibits weed establishment. We showed that the two weed suppressive cultivars of fine fescue were

able to grow as mixtures with Kentucky bluegrass to form strong sod (based on tensile strength) while also suppressing weeds. The outcomes specified for this project centered on communicating the research highlights to stakeholder groups across NYS. These venues are listed as the following:

Invited Speaker, Weed Identification and Control, Master Gardener Volunteer Training, May 12th, 2014, Webinar, NYS. Participants = 50, length in hours = 1, total contact hours = 50.

Invited Speaker, Weed Identification and Control, 2015 New York State Turfgrass Association Adirondack Regional Conference, March 18th, 2014, Lake Placid, NY. Participants = 40, length in hours = 2.5, total contact hours = 100.

Invited Speaker, Seasonal control of weeds in turf landscapes, Nassau Suffolk Landscape Gardeners Associations (NSLGA) Annual Conference, Uniondale, NY. Participants = 400, length in hours = 1, total contact hours = 400. February 24th, 2015.

Invited Speaker, Research and Extension Update, Sustainable Landscape Horticulture PWT, Webinar, January 22nd, 2015. Participants = 20, length in hours = 0.5, total contact hours = 10.

Invited Speaker, Weed Identification and Control, 2014 New York State Turfgrass Association Turf and Grounds Expo, November 12th, 2014, Rochester, NY. Participants = 40, length in hours = 2.5, total contact hours = 100.

Invited Speaker, Ecology of Weedy and Invasive Plants in Landscapes, 2014 New York State Nursery & Landscape Association Leader's Forum, October 28th, 2014, Ithaca, NY. Participants = 75, length in hours = 1, total contact hours = 75.

Invited Speaker, Control of Weedy and Invasive Plants in Turf & Landscapes, 2014 Southern Tier Nursery Landscape Association (STNLA) Annual Conference, Owego, NY. Participants = 100, length in hours = 1, total contact hours = 100. March 5, 2014.

Invited Speaker, Understanding the ecology of weedy and invasive plants to improve control, 2014 Nassau Suffolk Landscape Gardeners Associations (NSLGA) Annual Conference, Uniondale, NY. Participants = 300, length in hours = 1, total contact hours = 300. February 25, 2014.

Invited Speaker, Emerging techniques in IPM weed management for landscapes, 2014 Long Island Arboricultural Association Inc. (LIAA) Annual Meeting, Uniondale, NY. Participants = 50, length in hours = 1, total contact hours = 50. February 10, 2014.

Symposium Organizer, Turf wars and the emergence of pesticide bans in Canada and the U.S., 2014 Canada Weed Science Society (CWSS) and Weed Science Society of America (WSSA) Annual Meeting, Vancouver, BC. Participants = 60, length in hours = 4, total contact hours = 240. February 4, 2014.

Invited Speaker, Weed identification and control, 2013 Turf & Grounds Exposition, Rochester Riverside Convention Center, Rochester, NY. Participants = 50, length in hours = 3, total contact hours = 150. November 9, 2013.

The manuscript summarizing the research results is currently in preparation for submission to the *Crop Science* journal (April 2016) as the following: Panke-Buisse, K., Rossi, F., and J. Kao-Kniffin*. Fine fescue as a low-input, weed suppressive component of turf mixtures for organic landscape management*. In preparation for *Crop Science*

In the grant proposal, we described compiling a report from surveys on stakeholder feedback on research results. Based on an ongoing repetitive over seeding project (funded by the USDA CPPM program) we will combine with the results from both projects in a workshop specifically about non-chemical control methods for sports field pest management (at the November 2016 NYS Turf Expo).

Beneficiaries

The relevant stakeholders for the proposed project included members of the turf and landscape industries, school and daycare superintendents and groundskeepers, and community groups. Cornell Turfgrass has received many requests for resources from school superintendents and county Cooperative Extension Educators since the recent school pesticide ban was enacted. The proposed project was conceived in response to the demand by our stakeholders for practical alternatives to weed management on school grounds, daycare centers, and organically managed lawns and playing fields. The greatest beneficiaries of the proposed project are twofold:

1) The sod producers will develop a niche product that promotes and enhances weed suppressive turf;

2) School superintendents, lawn care providers, and landscaping businesses can utilize weed suppressive seed mixtures for organically managed turf landscapes.

NYS has 14 sod producing farms that cover 8,000 acres of land. Of the 14 sod producers, nine have voiced interest in producing economically viable sod that suppresses weeds. Weed presence in sod results in lost revenue for producers, ranging from $50,000 to $150,000 per year per farm. Providing weed suppressive sod benefits the NYS turf industries that rely on weed-free turf landscapes. In addition to sod producers, the benefit of weed suppressive turf can reduce the environmental impacts of fertilizer and herbicide use. Direct seeding of seed mixtures that establish into weed suppressive turf can improve turf management that requires organic practices, such as school grounds and daycare centers. With the turf industry of NYS valued at $5 billion annually, maintaining high value turf is essential for the NYS economy. Weed suppressive turf can stimulate new commercial niche opportunities for the NYS turf industry and help the industry adopt new management practices that adhere to the recent state-mandated pesticide restrictions.

We expect that the use of weed suppressive turfgrass mixtures in school and daycare grounds will maintain the value of turf in NYS at $5 billion annually, of which 10% should be associated with the benefits of providing new chemical-free strategies to manage turf.

Lessons Learned

Most of the project was kept on track to meet the major timelines. Establishing the turf mixtures in spring 2013 led to several problems concerning the biology of turfgrass establishment. In cool-season climates, such as the northeastern U.S., several turfgrass species have optimal germinate and establishment in late summer and early fall. We wanted to assess springtime establishment of the turfgrasses, but found that the Kentucky bluegrass varieties did not establish to acceptable levels. In early Fall 2013, we re-established the experimental design to assess turfgrass establishment later in the growing season when temperatures cool. We found that both the Kentucky bluegrass and fine fescue varieties germinated and established to acceptable levels for the proposed sod formation cover.

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Project 11
Increasing the Production Value of Vine Crops in New York State

Project Summary

Vine crop production is important to New York agriculture and generates $87 million annually. All vine crops require pollination by bees to produce fruit and growers supplement fields with honey bee (*Apis mellifera*) hives when crops are blooming. Unfortunately, Colony Collapse Disorder and high overwinter mortality continue to reduce honey bee populations throughout the US. Consequently, rental costs for honey bee hives have escalated to more than $85 per hive. Growers need alternative, less-expensive options to pollinate their vegetable crops and the common eastern bumble bee (*Bombus impatiens*), which occurs naturally and is available commercially, is a perfect candidate. This project was inspired from a previously funded SCBG project that suggested pumpkin fruit yields could be increased by supplementing pumpkin fields with bumble bee colonies, rather than honey bee hives. Moreover, we hypothesized that greater stocking densities of bumble bee colonies in pumpkin fields would result in greater fruit yields and higher profits for New York vegetable growers.

Project Approach

The extent to which pumpkin production requires supplementary pollination services beyond those provided by wild bees is not well documented. Two concomitant studies were conducted to examine pollination deficits in New York pumpkin fields. In the first study, fruit weight, seed set and bumble bee visits to pumpkin flowers were compared across fields supplemented with bumble bee colonies at a recommended stocking density of five colonies per ha, a high density of 15 colonies per ha, or not supplemented with bumble bees. In the second study, fruit weight and seed set of pumpkins that received supplemental pollen through hand-pollination (to maximize pollination) were compared with those that were open-pollinated by wild bees. Results from the first study indicated that supplementing pumpkin fields with bumble bee colonies, regardless of stocking density, did not increase fruit weight, seed set, or bumble bee visits to pumpkin flowers. Results from the second study indicated that fruit weight and seed set did not differ between hand- and open-pollinated treatments. Based on the results of these studies, we concluded that most pumpkin fields in New York are not limited by inadequate pollination services provided by wild bees and that supplementation with managed bees, either honey bees or bumble bees, is not required to maximize fruit yield. Therefore, in many cases growers can save input costs by not supplementing their pumpkin fields with managed bees.

The vegetable growers in the Finger Lakes region, who allowed us to conduct this research on their farms, were invaluable. While there were no direct costs provided by the vegetable growers for this research, most were willing to either not supplement their crops with honey bees or permitted us to bring bumble bees onto their farms rather than honey bees. Thus, they were taking risks of potential lower fruit yields by not supplementing their pumpkin fields with honey bees.

Goals and Outcomes Achieved

Measurable Outcome #1

Goal: This project was designed to include a cost-benefit analysis for producing fresh-market pumpkins in fields stocked at the recommended density of five colonies per hectare versus a higher density of fifteen colonies per hectare (=3 times recommended density) versus no supplementation of bees. The information should be transferable to other vegetable crops that require bee pollination.

Benchmark: No such information existed.

Target: The cost-benefit analysis was based on field research supported by this project. Outreach and education to vine crop growers in New York was accomplished through face-to-face contact and written material in publications and the internet. Results were discussed over the course of the year at the Empire State Fruit and Vegetable EXPO as well as other regional meetings. Results also were published in regional newsletters (e.g., Veg Edge) and trade magazines (e.g., Vegetable Grower News). We estimated that this information was delivered to fresh-market vegetable farms across the eastern U.S.

Performance Measure: Attendance at meetings was intended to be recorded by conference organizers and a survey will be given to participants to obtain feedback on the usefulness of the information and the level of savings and/or earnings they expect from the information.

Results: We presented our results at four grower-focused meeting throughout the duration of this study. The first meeting included two presentations on different aspects of this project at the Great Lakes Fruit and Vegetable EXPO in Grand Rapids, MI in December 2013. There were a total of 135 attendees. Another presentation was given at the Empire State Producers EXPO in Syracuse, NY in January 2014 with a total of 25 attendees. The final presentation was given at the Finger Lakes Vegetable Produce Auction in Penn Yan, NY with a total of 95 attendees. Based on the length of the presentations and numbers of attendees at these meetings, there was an estimated 156 contact hours.

We conducted a cost-benefit analysis to determine approximately how much money would be saved by reducing the acreage that does not benefit from supplementation by managed honey bees. We surveyed 16 growers in the Finger Lakes region with regards to how many acres of pumpkins they grow and whether or not they supplement with honey bees. Approximately 47% of the 380 acres of pumpkin grown in this region was supplemented with honey bees. Assuming this area was representative of the practices of growers in other parts of the state, we extrapolated this figure to New York State. Over the last five years, 3,161 acres of pumpkins grown in NYS were supplemented with bees (47% x 6,725 acres). We conservatively estimated that seventy-five percent of these fields likely do not benefit from supplementation (2,371 acres), which if growers were to adopt our recommendations would save more than $50,500 annually in pollination services costs (2,371 acres x 1 hive per 2.5 acres = 948 hives x $80 per hive = $75,872).

As a result of the information generated from this study, at least two of the largest pumpkin growers in the Finger Lakes region substantially reduced the number of bees they typically used to supplement their pumpkin crops. Neither grower noticed a reduction in fruit yield in the fields where bees were either not supplemented or the number of hives were reduced, saving each grower thousands of dollars.

Measurable Outcome #2

Goal: This project intended to update the Decision-Making Guide that vegetable growers may use to determine if their fields should be supplemented with commercial bees or if native populations of bumble bees are sufficient to pollinate the crop. We intended to update the guide to include new results regarding the optimal stocking density of bumble bees.

Benchmark: We currently have baseline data from 2011 to form the basis of a draft Decision-Making-Guide. The Guide was produced in its entirety at the end of 2012, but did not include any data on the basis for the recommended stocking density of bumble bees.

Target: The Decision-Making Guide was published as a fact sheet, disseminated in regional newsletters (e.g., Veg Edge, Muck & Mineral, etc.), placed on the Cornell Vegetable website http://www.vegetables.cornell.edu/ and was disseminated to fresh-market vegetable farms via the modes of communication described above.

Performance Measure: After determining the cost-benefit analysis and research results we discussed with producers at meetings and through face-to-face contact whether or not they will adopt the practices suggested by this study. To gauge adoption of the cost-benefit analysis, we will record any increase in bumble bee usage in vine crop fields including changes in stocking density of those that already purchase

bumble bees. We will accomplish this evaluation in two ways. First we will survey vine crop growers at the Empire State Fruit and Vegetable EXPO, Capital District Winter Meeting and other regional meetings in January 2013 about their use of managed pollinators in vine crops. We will repeat the survey in January 2014 at the same meetings as an estimate of the number of growers that have changed or are planning to change their practices. Second, we will work with Koppert Biological Systems to determine the increase in sales of their commercial bumble bees to New York vine crop producers.

Results: Because we did not determine that there was an advantage to supplementing pumpkin fields with bees in most situations, we decided not to modify the Decision-Making Guide or to survey growers who may have purchased bumble bees because our advice was that there was no need to supplement fields with bumble bees.

Beneficiaries

Vegetable growers, both conventional and organic, in New York State as well as those in nearby States should benefit from this project's accomplishments.

Because we did not observe increases in pumpkin yield in fields supplemented with bumble bees at typical or high stocking densities, our results indicated that supplementing pumpkin fields with bumble bees is not profitable to vegetable growers in most situations. Consequently, vegetable growers should benefit financially from our project because they do not need to rent bee hives to supplement the existing pollination services provided by wild bees.

We worked with 21 vegetable growers from the Finger Lakes region during our project yet only received feedback from 8 growers. Of these 8 growers, 7 reported that they benefitted from the research (88%). I know that growers outside the Finger Lakes region also benefitted, but I do not have the numbers. I think it would be fair to multiply the number of NY vegetable growers who grow pumpkins and squash by 88% to estimate the number who benefitted. Unfortunately, I do not have a list of NY pumpkin and squash growers in which to make that calculation.

About half the growers we worked with use either honey bees or bumble bees to supplement pollination in their pumpkin crops. Those who benefitted from our research reduced the number of hives they rent from 50 to 100% and saved between $500 to >$2000 per year on bee hive rental costs. All growers said that they observed no decrease in yield/ profits by reducing the number of hives on their farms. Therefore, the financial benefit to farmers was only in reducing the cost of renting bees.

The growers who never rented bees to supplement their crops in the first place told me that our research confirmed their belief that bees were not needed to supplement their pollination needs. These growers saved no money, but told me that they sleep better at night knowing that they are doing the right thing.

Lessons Learned

We were very surprised that supplementing pumpkin fields with recommended and three times the recommended densities of bumble bee colonies did NOT significantly increase fruit yields. We also did not observe more bees visiting pumpkin flowers in the pumpkin fields that were supplemented with these bees at the two stocking densities. These results were not expected and stimulated interest into investigating where the bees are foraging. While many of the bees foraged for pumpkin nectar, virtually none foraged on pumpkin pollen. Consequently, bumble bees would leave the pumpkin field in search of pollen and also likely foraged on nectar from other flowering plants. Foraging outside of pumpkin fields explains why we did not observe more bumble bees in pumpkin fields that had high bumble bee stocking densities.

Additional Information

A. Publications in Refereed Journals

1. Petersen, J. D., and B. A. Nault. 2014. Landscape diversity moderates the effects of bee visitation frequency to flowers on crop production. J. Appl. Ecol. 51: 1347-1356.
2. Petersen, J. D., A. S. Huseth, and B. A. Nault. 2014. Evaluating pollination deficits in pumpkin production in New York. Environ. Entomol. 43(5): 1247-1253.

B. Proceedings Articles

1. Nault, B. A., and J. D. Petersen. 2014. Supplementing pumpkins with bee hives: Is it worth it?, 4 pgs. Empire State Producers EXPO. January 22, 2014. Syracuse, NY. http://www.hort.cornell.edu/expo/proceedings/2014/Vine%20crops/Pumpkin%20Pollination,%20Petersen,%20Nault.pdf
2. Petersen, J., and B. A. Nault. 2013. Pollination of pumpkin in New York farms, 3 pgs. *In*: Great Lakes Fruit, Vegetable and Farm Market EXPO. Educational Program Abstracts. December 10, 2013. Grand Rapids, MI. Michigan State Univ. Extension. http://glexpo.org/summaries/2013summaries/FruitAndVegetablePollination.pdf
3. Petersen, J., and B. A. Nault. 2013. Abilities of wild bees to provide pollination services to pumpkin, 3 pgs. *In*: Great Lakes Fruit, Vegetable and Farm Market EXPO. Educational Program Abstracts. December 11, 2013. Grand Rapids, MI. Michigan State Univ. Extension. http://glexpo.org/summaries/2013summaries/VineCrops.pdf
4. Petersen, J. D., and B. A. Nault. 2013. Is it worth supplementing pumpkin fields with bees?, 4 pages. Empire State Fruit & Vegetable EXPO. January 23, 2013. Syracuse, NY. http://www.hort.cornell.edu/expo/proceedings/2013/Vine%20Crops/Vine%20Crops%20Peterson%20Supplementing%20with%20Bees.pdf

C. Extension Publications

1. Petersen, J., and B. A. Nault. 2013. Is it worth supplementing pumpkin fields with bees? Cornell Cooperative Extension, Cornell Vegetable Program. Veg Edge 9(2): 6-7.
2. Petersen, J. and B. A. Nault. 2012. Can pumpkin yield be increased by supplementing fields with honey bees or bumble bees? Cornell Cooperative Extension, Cornell Vegetable Program. Veg Edge 8(2): 4-5.

D. Trade Magazines

Petersen, J. D., and B.A. Nault. 2014. Landscape a factor when assessing pollination needs. Vegetable Grower News 48(3): 25-26.

E. Information on Web

Petersen J.D. and B. A. Nault. 2013. A decision-making guide for supplementing pumpkin fields http://rvpadmin.cce.cornell.edu/uploads/doc_67.pdf

F. Scientific Presentation

Petersen, J. D., and B. A. Nault. 2014. Effects of landscape features on foraging by honey bees (Apis melifera) and bumble bees (Bombus impatiens) in pumpkin fields. Entomological Society of America Annual Meeting. November 18, 2014. Portland, OR.

G. Presentations at Agricultural-Focused Meetings

Nault, B. A. 2015. Pollination in vine crops–it's all about the bees! Finger Lakes Produce Auction Growers Meeting. Cornell Cooperative Extension, Cornell Vegetable Program. January 8, 2015. Penn Yan, NY.

Nault, B. A., and J. D. Petersen. 2014. Supplementing pumpkins with bee hives: Is it worth it? Empire State Producers EXPO. January 22, 2014. Syracuse, NY.

Petersen, J., and B. A. Nault. 2013. Pollination of pumpkin in New York farms. Great Lakes EXPO. December 10, 2013. Grand Rapids, MI.

Petersen, J., and B. A. Nault. 2013. Abilities of wild bees to provide pollination services to pumpkin. Great Lakes EXPO. December 11, 2013. Grand Rapids, MI.

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Project 12
Intermediate and Advanced Organic and Sustainable Specialty Crop Grower Education to Increase Competitiveness in the Marketplace

Project Summary

The goal of this project was to increase the viability of NY organic and sustainable specialty crop operations by providing new tools and information. This proposal was designed in response to evaluation data gleaned from the 2012 NOFA-NY (Northeast Organic Farming Association-New York) organic farming conference and follow-up interviews. The evaluation showed that organic specialty crop producers in NY lack in-depth educational opportunities, are interested in networking with other advanced farmers, and seek the skills required to assess the efficacy of changes in their farm management. In response, this project provided technical information using farmers as teachers, university-based researchers, extension specialists, and other regional experts to provide a structured and multi-faceted learning opportunity.

The essential elements of the project were: 1) develop two technical courses in organic specialty crop production or marketing that meet participant technical needs and address a diversity of learning styles; 2) use enterprise analysis as a mechanism to assess changes in profitability based on the new practices adopted; 3) hold on-farm demonstrations of skills learned and tools implemented, providing a hands-on and/or visual form of learning for attendees and a broader audience; and 4) foster opportunities for advanced growers to meet other advanced growers and agricultural professionals to enhance collaborative learning.

This proposal responded to the growing demand for locally produced specialty crops for both wholesale and direct markets. Local food systems continue to gain strength throughout New York due to an increase in food safety concerns, diet-related diseases, the vulnerability of the energy supply, and increased consumer commitment to supporting local farmers. This project provided the resources for farmers to improve the viability of their farms through new production, marketing, and management skills. For some participating farmers, this meant increasing their capacity to meet the growing demand for fresh, locally produced specialty crops, while other farmers maintained their current level of production, but improved the efficiency of their production and management systems.

Project Approach

This project used a combination of technical courses and assistance, on farm learning experiences, and information sharing via the web and other digital and social media tools. Partners were engaged in annual planning and execution of the activities, and farmer feedback was a key driver of the design and evolution of the program. Programming and services were focused around two main goals:

- Goal 1: Increase intermediate and advanced organic and sustainable specialty crop growers' knowledge and efficiency in soil and fertility management by offering an intensive course and 1-2 complimentary field days each year.
- Goal 2: Increase intermediate and advanced organic and sustainable specialty crop growers' knowledge and efficiency in organic insect and disease management.

During year one of the project (2012-2013), informal surveying of advanced growers was held in preparation for the winter 2014-2015 intensive courses on organic insect and disease management. Growers submitted soil fertility, disease, pest and insect, and other topic suggestions for field day and intensive workshops. The partners planned the events and workshops and collaborated on event promotion and feedback. In years two and three, farmers and partners continued to be engaged in program design and roll

out via participation in the NOFA-NY Education Committee meetings, planning meetings, and informal surveys.

For all workshops and intensive training sessions, NOFA-NY conducted extensive outreach, documentation, and evaluation. Promotion for reach workshop reached over 9,500 subscribers to our eNews and events were also promoted via our Facebook and social media platforms (reaching 8,000+ subscribers). Two of the intensive workshops were promoted via direct mail to 700 farmers, and a number of the workshops were promoted via direct mail of the annual Winter Conference Brochure (5,000+ mailing) and the annual Field Day Brochure (1,400 mailing). Workshops were also co-promoted on our partner list-servs, eNews, social media, and web sites.

In addition to workshops and intensives, technical assistance was provided via phone, email, and in person on specialty crop topics through the course of the grant. An article appeared in the Spring 2014 issue of *New York Organic News* (reaching 800 members) about the use of row covers to manage pests and diseases on specialty crops, 4 blog posts were written and posted to our Facebook page (5,000+ subscribers). We also used social media to start alerting and educating farmers issues such as presence of late blight with significant reach and success. Also, during this time period, we conducted one-on-one technical assistance with advanced growers, including:

- Assistance in managing soil health and fertility in high tunnels, such as using sulfur to adjust high tunnel soil pH and use of organic materials vs. conventional for several acres of high tunnel tomatoes and cucumbers
- Several in-depth discussion with farmers who wanted on advice on transitioning their established vegetable business and/or business acquisition.
- Crop specific issues such as three sisters growing methods, dwarf Siberian kale, kohlrabi starts, starting an orchard, finding cider resources, and other fruit tree topics
- Soil health and fertility such as soil PH, use of organic compost, soluble fertilizers
- Disease identification and insect control issues, such as slug control

Over the course of the grant, a total of 8 intensive workshops were held at NOFA-NY conferences and on-farms. There were a total of 629 attendees at these intensive events. Virtually all of the intensive events were at capacity, illustrating the need for this type of programming. Below are highlights of these events:

- The first year's Soil and Fertility Management Field Day was held in Western NY on November 4, 2013 (this was scheduled to be held at a facility run by the federal government, and so had to be rescheduled from October 17, 2013 due to the partial shutdown of the federal government). NOFA-NY partnered with Cornell University Cooperative Extension and USDA NRCS Plant Materials Program to host this intensive full day field day and workshop focusing on Organic Cover Crops. Over 70 farmers and service providers attended to hear speakers from Cornell discuss nitrogen fixation and soil ecology, brassicas as cover crops, and to see demonstrations of cover crop interseeding. Jean-Paul Courtens, Roxbury Farm, discussed how they integrate cover crops on their vegetable farm, and NRCS's Paul Salon showed some quick soil quality tests before taking farmers on a great tour of his 320 cover crop plots. There was great turnout for the afternoon session (around 90 attendees) and enthusiasm, with some attendees traveling over 5 hours to be there, and both written evaluations and informal feedback were quite positive. Informal surveying of advanced growers was conducted in preparation for the winter 2014 intensive course on Soil and Fertility Management. The NOFA-NY Fruit and Vegetable committee met and provided topic suggestions and input. A formal survey was designed and was distributed to growers in the third quarter. We also held a meeting with the NOFA-VT staffer running their advanced intensive trainings, Lynda Prim, to learn from their experience doing similar trainings.

- The insect and disease intensive occurred in two separate one-day sessions, both in Geneva, NY. The first day was Tuesday, October 21, 2014, focused on "Organic Disease Management in (Another) Wet Year," and drew 35 attendees from approximately 27 farms. Presenters included Meg McGrath, Plant Pathology & Plant-Microbe Biology, Cornell Long Island Horticultural Research and Extension Center, Sarah Pethybridge, Professor, Cornell Plant Pathology and Plant-Microbe Biology, Abby Seaman, Vegetable IPM Coordinator and Extension Educator, and Chris Smart, Professor, Cornell Plant Pathology and Plant-Microbe Biology. These four presenters worked collaboratively to discuss a range of organic disease control practices and how growers can best deal with the most prevalent disease challenges seen in the last two extremely wet growing seasons. Topics covered included identifying, preventing, and controlling bacterial and fungal diseases, including downy mildew on a range of crops, black rot and alternaria on brassica crops, a wide range of soil borne diseases, and late blight on tomatoes and potatoes.
- The second half of the insect and disease intensive occurred at Bejo Seeds in Geneva, NY on Thursday, October 30, 2014. This session was an "Organic Brassica Production School," and drew 44 attendees from approximately 35 farms (12 of these attendees had also attended the first session). Presenters included Jan van der Heide, Bejo's Northeast Product Development Manager, Cornell Department of Horticulture's Thomas Bjorkman, Abby Seaman, Vegetable IPM Coordinator and Cornell Extension Educator, and Chris Smart, Professor, Cornell Plant Pathology and Plant-Microbe Biology. The session included a detailed overview of all aspects of brassica production including fertility management, insect and disease identification, and an examination of how cultivar selection should connect with plant spacing and soil fertility. Added emphasis was placed on flea beetles, Swede midge, black rot, and alternaria leaf spot, with samples of affected plants on hand. The day closed with an examination of marketing opportunities for organic broccoli and an optional tour of brassica field crop trials.
- At both workshops, attendees were satisfied with the instruction and discussion, and there were multiple requests for us to hold similar workshops in the future at the end of the season. In particular, attendees at the general Disease Management session, had vigorous discussion about what they were seeing and how they were (or weren't) able to control disease.
- The intensive Soil and Fertility Management workshop occurred as part of the 2015 winter conference on January 22 through January 25 in Saratoga Springs, NY. The soil and fertility intensive occurred in several sessions aimed at advanced growers, including one on-farm intensive, two classroom intensives, and two shorter workshop sessions. The intensive started on Thursday, January 22, with a full day (four-hour) session at Paul and Sandy Arnold's Pleasant Valley Farm in Argyle, NY. This on-farm day focused on managing soils and fertility for four-season growing, and included an overview of the Arnold's operations and greenhouses, as well as discussions of all aspects of winter cropping and their soil management strategies. 60 farmers attended from about 40 farms, and there was extensive time for farmer-to-farmer networking and discussion during the farm-catered lunch and after the close of the field day. Presenters Paul and Sandy Arnold went into details on all areas of their production, soil management, and finances, including sharing and discussing with attendees financial records and in-depth enterprise budgeting on the four season components of their farm, and how this budgeting impacts their management, scale, infrastructure, and cropping decisions. Attendees were hugely enthusiastic about this session, and really appreciated the experience and openness of the Arnolds. Evaluations showed that the majority of attendees learned a medium to a great amount about managing soil nutrition and amendments for extended season growing and the enterprise budgeting and farm economics of winter production systems.

- The next two intensives occurred each as simultaneous three-hour session on Friday, January 23, 2015, with over 100 farmers attending each session. For fruit growers, Hudson Valley farmer Hugh Williams, who incorporates a number of biodynamic and permaculture strategies on his Threshold Farm, led a session focusing on how to incorporate a range of ecological soil management strategies into perennial crops. UVM's Vern Grubinger led a highly interactive session for vegetable growers highlighting the newest soil and fertility management strategies while integrating a discussion of what trials and successes attendees have been seeing in their own operations.
- The final two sessions of the soil and fertility intensive occurred on Saturday and Sunday, January 24 and 25, 2015, drawing over 100 attendees to each session. Two of these shorter (75-minute) sessions were well attended and gave attendees the opportunity to see a more detailed case study of how experienced farmers incorporate the soil and fertility practices discussed throughout the intensive sessions into their farms' production and financial planning. Roxbury Farm's Jean-Paul Courtens and Jody Bolluyt discussed how their larger scale diversified operation builds and manages soil through a diverse range of cover cropping and rotation strategies. Paul and Sandy Arnold of Pleasant Valley Farm continued their discussion of managing around winter production, and how they set up fertility building systems in their greenhouse.

<u>Over the course of the grant, there were also 2 on farm field days. 32 attendees participated in these farmer to farmer learning experiences.</u>

- A summer on-farm field day on soil and fertility management occurred at Early Morning Farm in Genoa, NY on Sunday, August 10, 2014 drawing 18 farmer attendees. Farm owner Anton Burkett and farm production manager Chris Bickford led attendees through the areas housing their farm buildings, post-harvest handling facilities, caterpillar field tunnels and high tunnels, and their equipment yards, as well as two of their eight fields where they farm over 100 acres, marketing largely through CSA. Focus was on how Early Morning manages their tillage practices and fertility, as they move away from roto-tilling in favor of chisel plowing followed by a field conditioner. Discussion included both short term strategies and long term planning, and extensive discussion about the evolution from what strategies they used in the past and what systems and equipment they use today, including reducing tillage by using a heavy, high quality seeder and experimenting with under-sowing fall/winter cover crops on their fields with greater slope. Attendees were pleased by the workshop and there was excellent discussion among the attending farmers on how to deal with the challenges of maintaining high production levels while also building soil fertility. Feedback from this field day helped inform the topics and presentations of the upcoming soil fertility intensive which occurred in conjunction with the NOFA-NY winter conference, January 22 to 25, 2015, in Saratoga Springs, NY.
- A workshop was held at La Finca Del Sur in Bronx, NY addressing farm soil management and business strategies. 14 individuals attended the workshop. Nancy Ortiz-Surun, Farmer at La Finca Del Sur, provided the touring group with a brief history of the farm, as well as a summary of what it's like to farm in New York City. Their farm is divided into two nearly equal parts, a volunteer run farm, which sells produce at farmers markets in the Bronx, and a community garden, where members receive personal gardening plots.
- Carlos, another farmer at La Finca Del Sur, led the group on a tour of the site which included a greenhouse, storage shed, and newly built geodesic dome, which milkweed, bees and butterflies were voluntarily populating. Although La Finca Del Sur is not certified organic, they rely on sustainable growing methods; all of their community garden members must sign a contract stating they will refrain from using pesticides on the land. The farm grows exclusively in raised beds, since there is no way of knowing everything the land has ever been used for.

- Sara Katz, of The New York Botanical Garden's Bronx Greenup, detailed the process by which La Finca Del Sur mitigates contaminants through their raised beds. She also discussed phytoremediation, a soil remediation technique that uses plants to eliminate toxins from the soil. The discussion on soil health ended when Crystal Stewart, Regional Vegetable Specialist with Cornell's Eastern New York Commercial Horticulture Program, gave an overview of soil testing.
- The workshop also covered business planning considerations. Attendees received many handout materials detailing business planning strategies including enterprise budgets for specific crops, labor, and overall business budgets as well as a self-assessment marketing tool that allows new growers to customize their own marketing plan. Some of these materials were also posted on our website to increase the number of individuals who received the information.
- All attendees who completed our post workshop survey indicated that the workshop presented a medium to a great amount of new knowledge that caused all of them to make changes to their farming operations. While one person had not yet reviewed the financial impact of the changes made to their operation, everyone else anticipates that the changes they made will have a financial impact on their farm.

As a part of our website update, we completed the analysis of our existing resource page for farmers, identified inaccurate or outdated information to be deleted or updated, and identified new information on the latest organic research and information. This work compiled and being submitted along with the broader website update that is in process. As a result, it will be much easier for farmers to access relevant information in a timely manner. In particular, this will have an impact on the advanced growers that we would like to reach, as this will put information and tools more easily at their fingertips.

NOFA-NY specifically focused promotion for our events sponsored by this funding to small scale fruit and vegetable growers. The field day events were held at small scale specialty crop farms. The quarterly and final reports provided for this project detail that we have completed the activities that were approved in the project proposal.

Goals and Outcomes Achieved

Original Proposed Activity and Goal	**Actual Activity and Progress**	**Outcome**
6,500 farmers and gardeners throughout the Northeast will receive information about the courses through e-news and/or direct mailings.	More than 17,000 farmers and gardeners received information due to expanded reach of our eNews (9,500+) and social media platforms (8000+) in addition to standard mailings (700+).	Goal exceeded.
Planning begins for intensive courses in Yr. 1. 50 farmers attend the 2 learning courses (soils and pest/disease mgmt.): Y2: 25 attend one in CNY; Y3: 25 attend one in Hudson Valley.	Year 1 intensive drew more than 90 people. Year 2 intensive drew 79 over 2 days, Year 3 was held at the Winter Conference in Saratoga Springs. The soil and fertility intensive occurred in several sessions aimed at advanced growers, including one on-farm intensive, two classroom intensives, and two shorter	Goal exceeded. Held 8 intensives compared to the plan for 4, with 629 attendees compared to goal of 100.

	workshop sessions. 60 farmers attended the on-farm intensive, and more than 100 farmers attended each of the additional intensives and workshops (400 attendees)	
Participants complete evaluation after each course. Data impacts focus for field day.	Activity completed as planned	Goal achieved. Evaluations completed following each field day.
75 farmers will attend the 3 on-farm field days that provide practical hands-on complimentary information to the previous classroom workshops: Y1: 25 attend one in WNY; Y2: 25 attend one in CNY; Y3: 25 attend one in Hudson Valley.	Activity partially completed as planned. Two field days were held, one in WNY and one in the Bronx, with a total of 32 attendees. The team shifted its effort to more intensives due to the nature of the information to be communicated – see above. 1 of the field days was replaced with 2 intensive workshops at the 2015 Winter Conference, resulting in higher attendance overall than planned with standard field days. In addition to on-farm field days, 1:1 technical assistance via phone, email and in person was provided to farmers on a variety of specialty crop issues and topics.	Goal partially met: 2 field days with 32 attendees versus the plan for 3 field days with 75 attendees. Note that 1 field day was replaced with 2 intensive workshops at the 2015 Winter Conference, drawing 200 people. An additional 30 farmers received 1:1 technical assistance over the phone and via email.
Participants complete evaluation after each field day. Data impacts next year's programming.	Completed as planned.	Goal met.
Participants are evaluated to measure financial impact on their farm based on data from enterprise budgets or other recordkeeping as result of changes made from course learning.	Activity partially completed. Farmer feedback on the results and impact of the program was solicited both immediately post programs as well as at the end of the grant period with very positive results. However, collecting farm financial performance and attributing it to specific learning at the workshops was challenging due to staff turnover, variations in farmer use of the budgeting tools, and the highly unusual 2014-2015 growing season that significantly impacted many farmers' incomes and results. Impacts to the 2016 Winter season and beyond are not available during this grant period.	Goal partially met. 88% of farmer participating in the programming reported they planned to use the knowledge gained to improve or expand their operations. Upon resurvey at the end of the 2015 summer growing season, 3 farmers who responded to the survey reported they used the information to expand their markets, in particular into winter markets. Direct financial

		impact was not measured due to difficulties noted.
NOFA NY's website will host additional materials related to the courses and field days to provide support education for participating growers and the general public.	Posting of basic materials on website completed. During the final year of the grant, the NOFA-NY website was in the process of being updated. The entire portfolio of resources for advanced specialty crop growers was reviewed as a part of this process and materials and information will be relaunched on the new site in 2015. In addition, in year 2 – 3 of the grant, NOFA-NY introduced a blog and improved its use of social media as a forum for farmer education. Two key posts for advanced specialty growers, one on pests and diseases on brassicas and another on late blight were highly viewed.	Goal met and exceeded. Additional educational reach achieved via expanded use of blog and social media to alert farmers of the latest issues. 4 blog posts and 1 Facebook alert were completed during years 2-3 of the grant, reaching more than 5000 additional Facebook subscribers.

Beneficiaries

Primary beneficiaries of this project were sustainable or organic specialty crop farmers who identified themselves as being at an intermediate to advanced level. Participants in the workshops and intensives reported a high level of satisfaction with the programming, with 100% reporting they acquired new knowledge as a result of the programming and more than 50% reporting they learned a great amount from the programming. 89% of participants reported they planned to use the information learned in the coming growing year and 11% were unsure.

Our original goal was to directly reach 125 farmers in this project, and that was far exceeded as we directly reached nearly 650. Our goal was to indirectly reach another 300 farmers, however, that was far exceeded through the use of our social medial and blog platforms. Four blog posts were featured on our Facebook page with 5000+ users. These posts were among our most popular, frequently shared and also opened and read by as much as 25%-30% of our users.

Based on results from similar workshops in Vermont, we estimated that after the growing season in which the producer implemented changes as a result of participation in the courses, 75% of participants who conduct an enterprise analysis will increase their net profits by at least $1,000. Participants in the program were provided with tools for enterprise budgets and analysis. However, it was difficult to determine if these tools were consistently used by participants. While there were challenges in obtaining a precise net profit number from farmers during the course of this grant, 88% reported finding the workshops provided a medium to high level of new information, and 3 farmers who responded to a survey post 2015 summer growing season reported that they used the information from the programs to expand and improve their operations. The most common response was that the program helped them open up into winter markets. Although we were not able to complete the enterprise analysis as planned, these positive findings indicate that the net profits of participants were increased via this programming.

Lessons Learned

The demand and need for advanced growing education and outreach in specialty crops is significant. Our intensive programming was often "standing room only" and in some cases there were waiting lists to attend events. The use of the popular NOFA-NY annual Winter Conference as a venue for intensive training was very successful, providing a forum to combine and coordinate on a variety of topics. Partnering with others such as Cornell and NRCS, along with farmer experts, provided a vibrant learning experience for farmers by combining the latest scientific research with practical farmer know-how.

We exceeded our overall goal for the number of workshops and intensives and the number of beneficiaries and participants. However, the mix of programming was somewhat different than we expected. We found that the complexity of the training and information offered was better provided in a more intensive setting, and therefore we offered a higher number of intensive workshops than expected (8 versus 4), and a slightly lower number of less intensive field days (2 versus 3). We also found that attendance at intensive workshops far exceeded our expectations. We average 15-20 attendees at standard field day workshops; however, we routinely exceeded 100 at our intensive workshops. One intensive on farm day, at Paul and Sandy Arnold's farm in 2015, was filled to capacity at 60 attendees and had a significant waiting list. The shorter field days averaged 15 attendees compared to our goal of 25. It appears that the more intensive experience is what is valued and needed by advanced growers.

When the original proposal was developed in 2012, we did not foresee the power and role of social media as a farmer education tool. However, by the third year we found that our social media and web platforms were fast becoming not only a forum for promoting events, but also a place for effectively communicating key grower information on topics such as disease and pest management. This further expanded our reach beyond what we originally anticipated in 2012 and highlights the need for effective social media and web strategies going forward.

Overall, we were pleased and excited at the results of our program. Although variances in farmer use of formal budgeting tools and the unexpected impact of severe weather during the growing season made it difficult to draw concrete financial implications of our programming, the consistent feedback from farmers is that the programming was of high value in expanding their farming knowledge and improving the financial performance of their farms.

More work in advanced grower education is needed. Areas for continued education and development needed include areas such as:

- organic methods for managing soil health and fertility in high tunnels for the long term
- organic fruit production, in particular organic apples
- strategies for the emerging winter markets
- continued education on how to farm through the year to mitigate climate change issues and help farmers even out their revenue streams through the year

In addition, continued evolution of our tools and resources on our web site and social media platforms will be important into the future to augment vibrant farmer to farmer and hands on learning experiences.

Additional Information

- Web tools in enterprise budgeting**:**
  https://www.nofany.org/files/Advanced_Growers_Enterprise_Budget_worksheets.pdf

- Blog posts (which also posted to Facebook at www.facebook.com/nofanewyork)

  12/9/14 Planning and highlight the 2015 Winter Conference Intensives:
  https://nofanewyork.wordpress.com/2014/12/09/the-depths-of-planning-farmers-soil-education/

  10/13/14 Fungi, Bacteria, and viruses: https://nofanewyork.wordpress.com/2014/10/13/fungi-and-bacteria-and-viruses-oh-my/

  8/4/14 Late Blight: https://nofanewyork.wordpress.com/2014/08/04/be-prepared-for-late-blight-and-other-leaf-disease/

  10/9/14 Winter Squash https://nofanewyork.wordpress.com/2014/10/09/falls-royal-crop-growing-selecting-and-eating-storage-squash/

- Additional Facebook (www.facebook.com/nofanewyork):
  7/22/15 Late Blight https://www.facebook.com/notes/nofa-ny/late-blight-found-in-ulster-county-ny/10153088458066701

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